**Technical Report 1141**

# Coding Verbal Interactions In A Prototype Future Force Command And Control Simulation


**Paula J. Durlach**
U.S. Army Research Institute

**Laticia D. Bowens and John L. Neumann**
University of Central Florida
Consortium Research Fellows Program

**Thomas J. Carnahan**
Western Kentucky University
Consortium Research Fellows Program



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**A Directorate of the U.S. Army Human Resources Command**

**ZITA M. SIMUTIS
Director**

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Technical Review by

William R. Sanders, ARI
Donald R. Lampton, ARI

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As the U.S. Army undergoes transformation, it will need reliable means of measuring and training complex new skills. Acquiring those will require analysis of human behavior in the context of human-in-the-loop simulations of Future Combat Systems (FCS) still in the concept exploration phase. The goal of the present effort was to establish and measure command group behavior observed in such a human-in-the-loop simulation via analysis of the verbal interactions of the command group. A coding scheme for command group verbal interactions was devised and applied to several simulation runs in which a command group of 4 experienced Army Lt. Col.'s controlled an array of simulated unmanned air and ground platforms to accomplish a deliberate attack mission. This report documents the development of the coding scheme, the analysis results, and considers various other approaches for analyzing verbal data.

15. SUBJECT TERMS

FCS, Verbal Analysis, Verbal Coding, Command and Control, Battlefield Functions, METT-TC, Robotics, Future Force, C4ISR

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**Paula J. Durlach**
U.S. Army Research Institute

**Laticia D. Bowens and John L. Neumann**
University of Central Florida
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**Thomas J. Carnahan**
Western Kentucky University
Consortium Research Fellows Program



**Simulator Systems Research Unit**
**Stephen L. Goldberg, Chief**

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22304-4841

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## FOREWORD

As the U.S. Army undergoes transformation, members of the future force will need to acquire complex new skills in an environment of rapid doctrine, organization, training, materiel, leadership, personnel, and facilities changes and decreased deployment preparation time. A good understanding of the required Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) skills and a reliable means of measuring and training them will be essential. Acquiring those will require analysis of human behavior in the context of human-in-the-loop simulations of Future Combat Systems (FCS) still in the concept exploration phase.

This report documents the development of a coding scheme for the analysis of command group verbal interactions in such a human-in-the-loop simulation. Command group members were asked to "think out loud" so that their thinking processes could be captured among the verbal interactions. The analysis of their verbal interactions yielded a measurement instrument that can be used to help establish and assess training of the C4ISR skills required by the future force.

The work described in this report is a portion of the research performed under the FCS Command and Control (C2) program, led by the Defense Advanced Research Projects Agency (DARPA) and the U.S. Army Communications–Electronics Command (CECOM) Research and Development and Engineering Center (RDEC). As a program partner, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) focused on measuring human performance to improve human system integration and training and to support the Science and Technology Objective (STO) titled "Methods and Measures of Commander-Centric Training."

Findings from this effort were briefed to the Deputy Chief of Staff for Operations and Training from the Training and Doctrine Command (TRADOC DCSOPS&T). Methods and findings from each of the four experiments were provided to the Program Manager (PM) for FCS C2 as part of ARI's ongoing support to FCS and Army research and development efforts. Human performance findings by ARI helped shape the C2 prototype showcased in the FCS Capstone Demonstration of C2 systems prior to the FCS Milestone B decision.

MICHAEL G. RUMSEY
Acting Technical Director

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CODING VERBAL INTERACTIONS IN A PROTOTYPE FUTURE FORCE COMMAND AND CONTROL SIMULATION

# EXECUTIVE SUMMARY


Research Requirement:

As the U.S. Army undergoes transformation, members of the future force will need to acquire complex new skills in an environment of rapid doctrine, organization, training, materiel, leadership, personnel, and facilities changes and decreased deployment preparation time. A good understanding of the required Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) skills and a reliable means of measuring and training them will be essential. Acquiring those will require analysis of human behavior in the context of human-in-the-loop simulations of Future Combat Systems (FCS) still in the concept exploration phase. The FCS Command and Control (C2) program provides a working example of such a simulation. The program leads are the Defense Advanced Research Projects Agency (DARPA) and the U.S. Army Communications–Electronics Command (CECOM) Research and Development and Engineering Center (RDEC). As a program partner, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) focused on measuring human performance to improve human system integration and training and to support the Science and Technology Objective (STO) titled “Methods and Measures of Commander-Centric Training.”

Procedure:

The FCS C2 program created a transformation environment for empirical assessment of command group performance at the small unit level, the notional Unit Cell. From October 2001 to March 2003, the program conducted a series of commander-in-the-loop experiments at Ft. Monmouth, NJ. Over the course of the experiments, the digital command and control system—the Commander’s Support Environment (CSE)--became increasingly sophisticated, allowing the command group (of 4 people) to directly control 13 simulated unmanned air and ground vehicle platforms, and a set of unmanned ground sensors. The mission was consistently set in simulated desert terrain from the National Training Center (NTC) and required the Unit Cell to conduct deliberate attack missions against an enemy battalion to clear passage lanes for a follow-on force.

The ARI partners developed analyses of critical command group functions, and described player reactions such as workload assessment, and CSE strengths and weaknesses. The data for this work consisted of the verbal interactions among the experiment participants in the Unit Cell, their computer interaction activities, and their responses to questionnaires. The present report is concerned specifically with documenting the coding scheme used to analyze the verbal interaction data. Unit cell members were asked to “think out loud” so that their thinking processes could be captured among the verbal interactions. The verbal interactions of the Unit

Cell for selected experimental sessions were transcribed and content was analyzed for Function (Plan, See, Move, Strike, Battle Damage Assessment), Source (who was speaking), Type of communication (e.g., question, declaration, etc.), and Factor (Mission, Enemy, Terrain, Troops, Time, Civilians). As well as documenting the coding scheme and presenting illustrative results, this report also includes recommendations for further refinement of the coding scheme.

Findings:

A striking finding from the analysis of verbal interactions among the Unit Cell members was that sharing of information was consistently the most frequent type of verbal interaction (as opposed, e.g., to questions or directions). Despite the fact that all Unit Cell members did have access to the same database of information, it was still essential to verbalize about data that were observed in order to maintain a common operating picture. Analogously, See was always the most frequently observed Function (defined as "Detect or identify enemy or friendly positions, or significant terrain aspects"). This result has significant implications for communications requirements for the FCS, intended to be a netcentric system of systems supporting a distributed force. Specifically, one implication is that a networked information system, allowing all users to access all information may still not be sufficient to maintain a common operating picture. Due to the vastness of the data available, and the limitations on the human information processing system, some means of directing users to the most relevant information is going to be required. In the present research, this was accomplished by participants telling one another what they believed they should know. It should be kept in mind however, that participants were instructed to "think out loud." This may have distorted the type of verbal interactions observed, compared with participants not so instructed.

From a methodological point of view, there were several findings. A workable coding scheme for analyzing command group verbal interactions was established. This scheme proved sensitive enough to discriminate the verbal behavior of an expert vs. a novice command group, and to discriminate the verbal behavior observed in mission execution vs. mission planning.

Several issues were tackled, such as how finely to analyze the verbal data (what constitutes a data point?). The issues involved in developing a coding scheme for verbal data were explored and the advantages and disadvantages of different approaches were illustrated. In particular, we found a trade-off between the granularity of analysis and the ability to capture in coded data, verbalizations reflecting command considerations and more abstract thinking and decision making. In the final conclusion, it is suggested that the most useful coding scheme would be one specifically tailored to support hypothesis-driven research.

Utilization of Findings:

This work established a coding scheme for analyzing the verbal interactions of a command group during mission planning and execution. This measurement tool can now be used further to measure, help establish, and assess training of the C4ISR skills required by the future force.

CODING VERBAL INTERACTIONS IN A PROTOTYPE FUTURE FORCE COMMAND AND CONTROL SIMULATION

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# CODING VERBAL INTERACTIONS IN A PROTOTYPE FUTURE FORCE COMMAND AND CONTROL SIMULATION

## The Experimental Context

Between 2001 and 2003, the Defense Advanced Research Projects Agency (DARPA) conducted a series of experiments on Future Combat Systems-Command and Control (FCS-C2). These experiments were designed to assess the FCS concept that a small group of people, supported by a digital command and control system (C2) and several unmanned and some manned platforms, could fulfill the functions of a traditional U.S. Army command and staff organization. In conjunction with the U.S. Army Communications-Electronics Command (CECOM) Research and Development Center (RDEC), DARPA has conducted five warfighter-in-the-loop experiments focused on Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) at the Unit Cell and team level.

For four of the experiments, the cell participants were the same four U.S. Army Lieutenant Colonels, though on occasion, one or more of them were replaced by other players. The remaining experiment used West Point Cadets and university ROTC students. Four cell positions were labeled as Commander, Battlespace Manager, Effects Manager, and Intelligence Manager. These players sat in a mock-up C2 vehicle, each equipped with two computer screens, which could display information from the digital C2 system, the Commander's Support Environment (CSE). Each operator controlled their own displays. After Experiment 2, an additional display was added--a Head Up display that could be seen by all positions. Any player could put one of their screens on the head's up display, in order to facilitate interactions and discussions with the other positions.

One major technical effort involved development of the digital C2 system—the Commander's Support Environment (CSE). The CSE is defined as a hardware and software, networked environment that enables command and control of the FCS Unit Cell. It provided visual displays, control of unmanned platforms, computing, and communications infrastructure (DARPA, 2001). Ideally, the CSE provides the right information, at the right place, and at the right time, to enable the command group to handle emerging conditions and accomplish their mission. Over the course of the experiments, the CSE evolved and drew closer to this ideal. For example, in Experiment 1, operators had no ability to control their own fires, but had to call a higher echelon to request fires. In contrast, by Experiment 4, operators could not only control their own fires manually, but also had an Attack Guidance Matrix (AGM) which would cause the unmanned platforms to launch fires automatically, according to a set of conditions configured set of conditions. Many of the modifications made to the CSE over the course of the experiments were based on feedback from the four main participants.

The CSE was bridged to One-SAF Testbed (OTB) to allow for mission simulation. Another technical effort involved refining the behaviors of the simulated assets of the cell. The configuration of assets included four micro-unmanned aerial vehicles (UAVS), and a Shadow UAV (a large sized UAV). These were typically controlled by the Intelligence Manager. There were two line-of-sight (LOS) ground robotic weapons platforms, two Roboscouts (ground robotic sensors), and two future-warrior carriers (FWC), from which computer generated infantry could be dismounted. The Battlespace Manager typically controlled these assets, and any ground maneuvers. There were two nonline-of-sight (NLOS) ground robotic weapons platforms typically controlled by the Effects Manager. Finally, there were two reconnaissance UAVs (A-160s), controlled at a higher echelon, which could be requested for specific reconnaissance missions. The CSE included a situation awareness map that displayed the locations of these assets as well as detected enemy or other elements, these being displayed at varying levels of confidence and identification. The CSE was used for control of all assets and provided several aides to the operators (e.g., customized alerts, terrain analysis features). Besides the four Unit Cell members working with the CSE, after Experiment 1, the C2 vehicle itself also had a human driver and gunner with their own displays.

In addition to the players in the C2 vehicle (Black Cell), there were other cells that were partly manned, and partly semi-automated forces (SAF). The Blue Cell represented one echelon up from black, and controlled the two A-160s. The White Cell represented blue's higher; white did not participate much in the last few experiments, at least verbally. The Red Cell represented the enemy cell.

Each experiment consisted of several sessions run over two weeks time, with each session lasting from about 30 minutes to two hours. Shorter sessions were usually curtailed due to technical difficulties; otherwise they were terminated according to the judgment of the project manager or operator/controllers. During each session, the cell's mission was similar: to traverse from one position to another, and secure the passageway and second position with the intention of ensuring safe passage of a second (theoretical) follow-on Unit Cell. Each session began with the delivery of intelligence information to the cell, a planning phase in which they planned the mission, and an execution phase in which the mission was conducted. For Experiments 1-3, the strength of the opposition forces was systematically varied across sessions. After-action reviews (AAR) were conducted for each session by expert analysts.

Prior to each experiment, participants underwent varying amounts of (unstructured) training, to familiarize them with CSE operations and any upgrades that had been made since the previous experiment. The amount of training was subject to program technical progress and the translation of this into training materials.

## U.S. Army Research Institute Role

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) (Armored Forces Research Unit at Ft. Knox and Simulator Systems Research Unit at Orlando) supported this research, by conducting analysis of the participants' behavior during the experiments, and their reactions to their experience. From ARI's perspective, this research contributes to the Science and Technology Objectives (STO), Methods and Measures of Commander-Centric Training. As part of that STO effort, ARI is investigating the requirements for training army officers to perform complex C4ISR activities that encompass multiple traditional military functions. The FCS concept entails an unprecedented alliance of humans and machines at the small unit level and the C4ISR behaviors of the command group for an FCS Unit Cell need to be investigated and understood. The ARI research developed detailed analyses of critical command group functions, and measured player reactions such as workload assessment, and CSE strengths and weaknesses. The data for this work consisted of the verbal interactions among the Black, Blue, and White cells, questionnaire responses from members of the Black cell, and human-computer interaction activities. The ARI research for this project is reported in detail in the reports: FCS C2 Human Functions Assessment: Interim Report, for Experiment 1 (Sanders, Lickteig, Durlach, Rademacher, Holt, Rainey, Finley, and Lussier, 2002), for Experiment 2 (Lickteig, Sanders, Durlach, Rainey, and Carnahan, 2002), for Experiment 3 (Lickteig, Sanders, Durlach, and Carnahan, 2003), and for the student research (Carnahan, Lickteig, Sanders, and Durlach, in preparation). The present report is concerned with documenting the development of the coding scheme used to analyze the verbal data. Results will be presented for illustrative purposes. Readers wishing more detailed data on the verbal analysis, or on the other measures examined are referred to the reports listed above.

## Development of a Coding Scheme for Verbal Interaction Data

This report describes the development of the coding scheme for analysis of the verbal interactions recorded during selected sessions over the course of the four experiments with the primary players. Verbal data are recognized as a window on the psychological mechanisms and knowledge structures underlying problem-solving activities (Ericsson and Simon, 1993; Yang, 2003). During these experiments, players were encouraged to "think out loud" and indeed, players did speak during approximately 96% of each experimental session. Written transcripts were compiled, using audio recordings of specific sessions. These transcripts served as the basic data for analysis. The goal of the analysis was to determine and characterize the C4ISR behaviors of the Unit Cell.

At a high level, the function of command group actions is to C2 the Unit Cell and accomplish the assigned mission. A candidate set of functions adopted initially was:

- Plan: Develop, assess, and modify a plan including combat instruction sets provided to robotic elements in response to changing events.
- Move: Control the movement and activity of friendly manned and unmanned systems to maintain desired movement rates and formations.
- See: Control and interpret input from a heterogeneous set of advanced sensors to mentally construct an accurate picture of enemy activity and intent.
- Strike: Distribute a variety of indirect and direct effects over a set of targets.

The challenge was to relate these functions to the observed verbal data, characterize their relative frequency and time duration, and elaborate the verbal classification scheme further. To facilitate elaboration, the team reviewed the draft CSE Functions Manual (DARPA, 2001), which identified equipment functions of CSE system operation. The team also reviewed the literature regarding C2 group functions and task classification strategies, and identified several candidate C2 activities to consider for use in coding Experiment 1 verbal communications data. The coding scheme arrived at coded for:

- Source: Who was involved in the verbal interaction.
- Function: Plan, See, Move, Shoot.

- Factor: 21 subfactors assigned to one of the following larger categories of Mission, Enemy, Terrain, Troops, Time, and Civilians (METT-TC).

In order to apply this coding scheme, the team decided to break each session transcript into "chunks" of words, with each chunk addressing a single topic (as recommended by Ericsson and Simon, (1993). It was intended that one code for each of Source, Function, and METT-TC factor be assigned to each chunk. Ideally, the code to assign for each block should be unambiguous. This requires both that the coding categories are clearly defined (what does a particular code mean), and that each chunk only have one code appropriate to its content. Unfortunately, human verbal interaction is not simple. People do not interact in a strictly linear way, and discussions don't necessarily involve one and only one topic (Yang, 2003). This means that the chunking of the dialog itself involves important assessment on the part of the researcher as to when one chunk should end and another begin. The way in which the raw transcript is chunked will influence how unambiguously the coding scheme can be applied, and in particular, whether independent raters agree on the codes to assign.

The level of analysis to examine behavior is a perpetual issue in psychological science. When looking at behavior from a "high" level, it may be too complex to apply quantitative measures to, or be open to several different interpretations, such that the objectivity of the analysis can be questioned (e.g., the quality of the performance of an orchestra). Looking at behavior from a detailed molecular level tends to lend itself more to quantitative analysis and increasing objectivity, but this can also be at the loss of "the big picture" (will analyzing the individual finger movements of each musician help the researcher understand the quality of the orchestral performance?). The question of how finely to chunk session transcripts has been an issue throughout this work. For Experiment 1, chunks consisted of fairly large pieces of dialog. One ARI researcher and one Active Duty Army Major independently coded the chunks for each of the nine sessions, compared their results, and then reached agreement on a single set of codes for each chunk. To develop an empirical estimate of inter-coder agreement the ARI researcher and the first author coded four session transcripts independently and compared their results. There was rather poor inter-coder agreement (74% for Source, 63% for Function, and 55% for METT-TC). The goal was at least 80%. The main problem seemed to be that the chunks were too large, and that more than one code could be applied to each one. When two or three codes were potentially applicable, it was then a matter of subtle interpretation as to which one of those a particular coder selected. It was clear that for subsequent experiments, the chunks needed to be more fine-grained and that guidelines for chunking needed to be developed. A sample of unchunked and uncoded transcript can be found at the end of this report.

The revised coding scheme developed was based both on these considerations and the substantive content of the results of Experiment 1 (i.e., what it was that the players actually talked about). The essence of this scheme--the common elements that were used for Experiments 2-4—is outlined in Tables 1-4. Over the course of Experiments 2-4 some additional categories were used as well; these will be discussed subsequently. There were four codes assigned to each chunk, one from each of the code categories Type, Source, Function, and Factor.

Interaction type (e.g., commands, questions, observations) to categorize verbal interaction has proven a useful predictive variable of team performance (Kanki, Folk, and Irwin, 1991). For the present work, the Type category (see Table 1) was introduced primarily to guide chunking. Chunks were initially determined by segmenting the verbal data into passages of different interaction types. Share, Action, and Direction were relatively short interactions, without a lot of discussion. Chunks including a lot of discussion or consideration of multiple aspects of a situation were designated either Process or Decide. These were distinguished by whether there was a definite conclusion reached by the participants (Decide) or not (Process).

The raw transcripts were initially chunked according to Type by one coder (the first author). This resulted in finer-grained chunks than in Experiment 1; however, it still led to several chunks for which multiple METT-TC subfactor codes were applicable. Therefore, a two-stage process of chunking was used. After the raw transcript was chunked according to Type, on a second pass, chunks were further subdivided if multiple METT-TC subfactor codes could be applied to the chunk. In addition, overlapping interactions (e.g., two pairs of people having separate conversations at the same time) were separated, when intelligible, such that each conversational stream became a separate chunk. For Experiments 2-4, the chunking was always carried out by the same person (the first author), and no attempt was made to assess whether other coders agreed with the chunking.

The remaining coding categories were Source, Function, and METT-TC Factor as laid out in Tables 2, 3, and 4. Source coded for the participants in the verbal chunk. Function coded for the broad C2 function under discussion. In addition to the Plan, See, Move, and Shoot codes (now relabeled Strike), as used in Experiment 1, two additional Function codes were added: Battle Damage Assessment (BDA), and Other. BDA was added as it seemed a very important issue for the cell, which should be coded as a separate item. Because missions were conducted from a stand-off position, progress of each mission depended on obtaining reliable BDA. The code "Other" of the Function category was added to capture any other activities that did not fit with the specified functions. METT-TC Factor category coded for traditional Army information categories. Under the factors of Mission, Enemy, Terrain, Troops, Time, and Civilians, 25 sub-factors were specified to capture the detailed information discussed during each session. Each chunk was assigned one of the 25 subfactor codes, and then related the METT-TC factors, as laid out in Table 4.

Table 1. The Type Category used for coding Experiments 2-4

| | |
|---|---|
| 1 | Share. Announcement, telling what is <u>seen or known</u>. |
| 2 | Action. Announcement, telling what <u>speaker</u> is doing at the moment--verbalization <u>accompanying action such as fire or move</u>. Not the decision process. Not actions such as I see, monitor, track, etc. Not describing someone else's actions. |
| 3 | Direction. Order, command, delegation of responsibility. |
| 4 | Ask. Interaction <u>begins</u> with request for information, confirmation, assistance, or assets and <u>ends either with informational answer or no response</u>, with little or no discussion. Not rhetorical questions. |
| 5 | Process. Infer, synthesize, fuse, understand, turn data into information <u>without</u> consequent decision or direction. <u>Can</u> start with Share, Action, or Ask. |
| 6 | Decide. Like Process, <u>but in addition, includes a verbalized decision or plan</u>. |
| 7 | Other. |

Table 2. The Source Category used for coding Experiments 2-4

| | | |
|---|---|---|
| 1 | Within Cell (Black) | Cell = 4 CSE operators |
| 2 | Cell <-> Blue (Team) | |
| 3 | Cell <-> White (Higher) | |
| 4 | Cell<->Subordinate | Subordinate includes $C^2$Vehicle gunner & driver |
| 5 | Blue<-> White | |
| 6 | More than 2-way (e.g., Cell<->White<->Blue) | Only to be used in cases where more than 2 elements involved in SAME conversation |
| 7 | Other | E.g., to technical support people |

Table 3. The Function Category used for coding Experiments 2-4

| | | |
|---|---|---|
| 1 | See | Detect or identify enemy or friendly positions, or significant terrain aspects. (not BDA) |
| 2 | Plan | Interpret data, predict enemy COA, generate own COA |
| 3 | Move | Manage/Monitor/Control asset movement |
| 4 | Strike | Manage/Monitor/Control lethal/nonlethal effects |
| 5 | BDA | See for purposes of BDA |
| 6 | other | None of the above |

In order to assess the objectivity of the coding scheme, results were assessed for inter-coder agreement. First, two coders (the first author and the fourth author) coded a single session from Experiment 2 independently, and then discussed their codes for each chunk, focusing on those chunks for which their codes differed. Nuances in interpretation were debated, and through this, a common understanding on how to apply the codes was achieved. The two coders subsequently coded two additional sessions and their probability of agreement for each session was calculated, as shown in Table 5. As can be seen in Table 5, the level of agreement was relatively good, and definitely an improvement over Experiment 1. For Experiments 3 and 4, the coding was conducted by one coder only (the first author).

It should be noted that, for Experiment 2, we also tried a more automated form of analysis, by using key-word or phrase searches and counts. For example, by counting the number of times the phrase "I think" occurred and other such phrases, it might be possible to arrive at a quantitative measure of the number of situation assessments made by the cell. In practice, however, it turned out that there were many times that key-phrases were used in a way that had little or nothing to do with their intended interpretation, as well as instances that clearly did fit with the intended interpretation but without mention of a key phrase. Thus, this approach did not really yield useful data in and of itself. It is possible that now that more transcripts have been coded, a re-analysis of the phrases used most commonly for each code set might reveal more successful search targets.

Table 4. The METT-TC Factor Category used for coding Experiments 2-4

| | |
|---|---|
| MISSION | |
| 1 | Original Plan: Concerning mission goals and plans prior to execute phase. |
| 2 | Dynamic Planning: Tactical re-planning during the execute phase in response to changing events and available assets. Must have stated COA (course of action). Changes from Original Plan. |
| 3 | Situational Understanding. Integration/summary of current situation involving multiple factors; but without stated COA. |
| ENEMY: Concerning enemy situation including | |
| 4 | Location: Sensor hit(s) – locate enemy positions. |
| 5 | Identification: Identify targets – identify nature of enemy target. |
| 6 | Disposition: Probable enemy COA, strategy, or tactics. |
| 7 | BDA: Battle Damage Assessment – cell seeks/discusses feedback on damage they inflict on enemy. |
| TERRAIN | |
| 8 | When terrain is the prime focus (e.g., can we travel over that kind of terrain?, we should go this way because it will provide cover). Example: "Moving to low ground." Not simply map locations (e.g., not, sensor hit north of the wall). |
| TROOPS and Assets (Soldiers, Equipment, Vehicles)<br>FRIENDLY ONLY | |
| 9 | Location Status: Position report/assessment |
| 10 | Movement Status: Mobility report/assessment (includes fuel) |
| 11 | See Status: Sensor report/assessment |
| 12 | Strike Status: Fire power report/assessment (includes # of remaining missiles) |
| 13 | Communications/network functionality (radio, internet, or other; cell to outside cell, including semi-autonomous sensors). |
| 14 | Information management systems: CSE user interface tools |
| 15 | Survivability Concern: Asset in danger. |
| 16 | Survivability Move: defensive move to remove asset from immediate danger. |
| 17 | Loss/Casualty: Asset destroyed (catastrophic hit). |
| 18 | Move Action: Move/Manage/Maneuver [Active, Not position report]<br>Excluding Survivability Move; Also See Terrain. |
| 19 | Strike Action Lethal: Launch/fire/deploy with intent to destroy (includes LAMs) |
| 20 | Strike Action Nonlethal: Launch/fire/deploy (could include unarmed sensors, propaganda, smoke, jamming of enemy, etc.). |
| 21 | Training (Soldier training, mission rehearsal) |
| 22 | Other-- having to do with troops or assets but none of the above |
| TIME | |
| 23 | When time is the prime focus (e.g., how much time something will take, how much time is available, order of priority, synchronization of actions). |
| CIVILIANS | |
| 24 | Any issues regarding how to deal with civilians: avoiding, provisioning, protecting, etc. Not mere sensor hits of civilians, unless first time mentioned. |
| OTHER | |
| 25 | Other (e.g., humor, personal, leadership, morale) |

Table 5. Probability of inter-coder agreement for 2 sessions of Experiment 2

| Session Number | Type | Source | Function | Factor |
|---|---|---|---|---|
| 6 | .94 | .99 | .94 | .89 |
| 8 | .87 | .99 | .92 | .86 |
| Chance * | .14 | .14 | .17 | .04 |

*Probability of chance agreement based on number of potential codes for the category.

## Results of Experiments 2-4

To illustrate the substance of the results obtained, the data from one session from each of Experiments 2, 3, and 4 will be presented. It should be remembered that these data reflect only what was verbalized by the participants. Low values on some of the categories don't necessarily indicate that those activities were not engaged in frequently, only that they were not talked about frequently. A good example is the Action code, of the Type category. The Intelligence, Battlespace, and Effects managers were all quite active using the CSE controls throughout each session; however, they did not necessarily report on all their activities to the rest of the group.

Table 6 illustrates some key characteristics of the three sessions. As can be seen in Table 6, the three sessions were of approximately equal duration, with verbal data collected during more than 95% of each session. On average, each chunk lasted 11.4 seconds, and consisted of 26.7 words.

Table 6. Key Characteristics of the verbal data

| | Experiment 2 | Experiment 3 | Experiment 4 |
|---|---|---|---|
| Run Duration | 87 minutes | 89 minutes | 90 minutes |
| Cumulative Silence* | 2.3 minutes | 2.9 minutes | 3.75 minutes |
| # Verbal Chunks | 494 | 461 | 408 |
| # Words in transcript | 11,984 | 12,329 | 11,848 |

*Timing initiated after 3 seconds of silence

Figure 1 illustrates the verbal data coded for Type of interaction, and Table 7 lists selected chunks to illustrate each Type code. As can be seen in the figure, the distribution of chunks across the Type codes was very similar across experiments. The most frequent type of interaction was always Share (an announcement telling what is seen or known). Share interactions tended to be relatively brief. Their frequency indicates the importance of the cell members keeping one another "on the same page." Despite the fact that they shared the same digital C2 system, each operator configured their system in a unique way, such that they were rarely all looking at the same display configuration. Their use of the head's up display (not captured in the coding scheme), indicates the requirement to refer to a common picture. That head's up display was actually requested by the operators after Experiment 1. The feeling of the need for a head's up display, and the frequent Share verbalizations suggest that provision of a common digital C2 system is not sufficient to maintain a common operating picture.

Next most frequent were Ask and Direction, with their relative frequency dependent on the particular session. These were also fairly brief interactions. For example, Ask typically involved a request for some information, followed by a straight forward answer. Direction typically involved a request for some action to be performed and an acknowledgement. Least frequent were Action, Process, and Decide. Process and Decide, by definition, tended to be relatively longer chunks with multiple interactions. Their low frequency does not necessarily imply that the cell paid insufficient attention to thinking things through. A clear relation between mission performance and Type frequency would be necessary to demonstrate this. Unfortunately, the ability to relate the verbal data to mission performance was not possible, as mission performance assessment was not available for analysis (there were AAR sessions, but the data from these were not captured formally for later analysis).

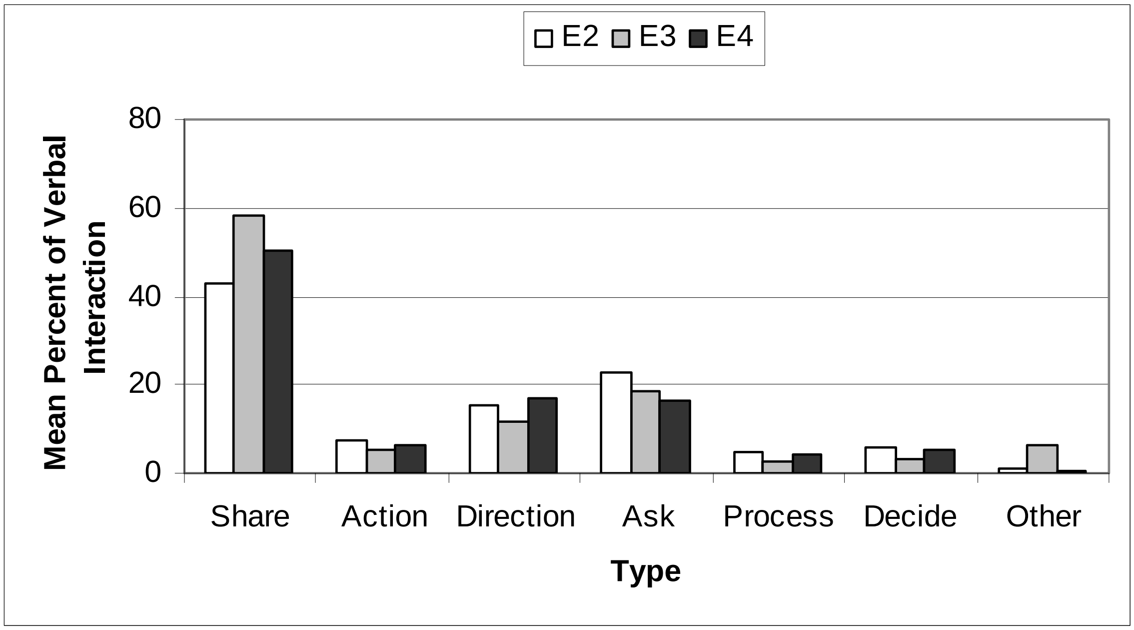



Figure 1. Relative percent of verbal interactions assigned each type code, for one session from each experiment (E2-E4).

Table 7. Example chunks for each Type code. Note: these are not consecutive chunks

| Speaker | Verbal Data | Type |
|---|---|---|
| | | |
| Intelligence Manager | There's a target that popped up there from our Elint.<br>I believed that popped up from our Elint--this Daria.<br>Let me just find out a little more information on this. | Share |
| | | |
| Commander | Alright, I'm firing two UGS with netfires 1 | Action |
| | | |
| Commander | Alright, here's what I want you to do, Ken. | Direction |
| Intelligence Manager | Yes, sir. | |
| Commander | I want to fly that SAR path with the A-160. Then, when it gets done painting that northern sector, turn it back to MTI. Then turn our SAR-Bird back on and put SAR-Bird back in on yellow. Okay? | |
| | | |
| Commander | Where's my shadow at? | Ask |
| | | |
| Battlespace Manager | He's moving…the MTI track has him moving east. | Process |
| Commander | He's going to go around. I think what he is going to do is go around that hill mass and come down by Karen. | |
| | | |
| Commander | Blue6-Black6 | Decide |
| Blue | Blue. Over. | |
| Commander | Alright Blue6-Black6. Initial read of the battlefield is that he is defending forward with a heavy security zone established along the FLOT. Break. I detect at least 2 platoons forward along the FLOT supported by air defense artillery. Break. Additionally, it looks like he's also got some concentration in the center. Therefore I suspect a heavy forward defense, a heavy security zone with a mobile defense more than likely coming from the center sector. Break. Therefore I think I've got all the information I need to begin executing decision point 1 and our attack in the north. Over. | |
| Blue | Roger, I think you'll find more by Granite Pass, on the back side of Iron Triangle. I think we have a good read. Over. | |

Table 8 shows the verbal data for each session, coded for the Source category. Clearly the vast majority of verbal interactions were among the Black Unit Cell managers. The next most frequent interactions were between the Black cell and their driver or gunner (subordinates) and between the Black cell and the Blue cell. Interactions listed as other typically involved members of the Black cell and either technicians supporting the simulation or visitors observing the simulation from within the C2 vehicle room.

Table 8. Mean percent of verbal interaction observed for each code of Source category

| Source code | Experiment 2 | Experiment 3 | Experiment 4 |
|---|---|---|---|
| Within Black Cell | 84.0 | 86.1 | 84.6 |
| Black - Subordinates | 7.9 | 3.7 | 10.0 |
| Black - Blue | 5.1 | 4.6 | 3.9 |
| Black - White | 0.8 | 0.0 | 0.0 |
| Blue - White | 1.2 | 0.0 | 0.0 |
| 3-way | 0.4 | 0.0 | 0.0 |
| Other | 0.6 | 5.6 | 1.5 |

Figure 2 illustrates the verbal data categorized according to the Function codes. As can be seen in Figure 2, the distribution of Function across the different codes was quite similar across the three sessions (and all the mission execution sessions that were analyzed). See was always the most frequently verbalized Function, followed by Move or Strike, depending on the particular session. This was followed by BDA and then Plan and Other.

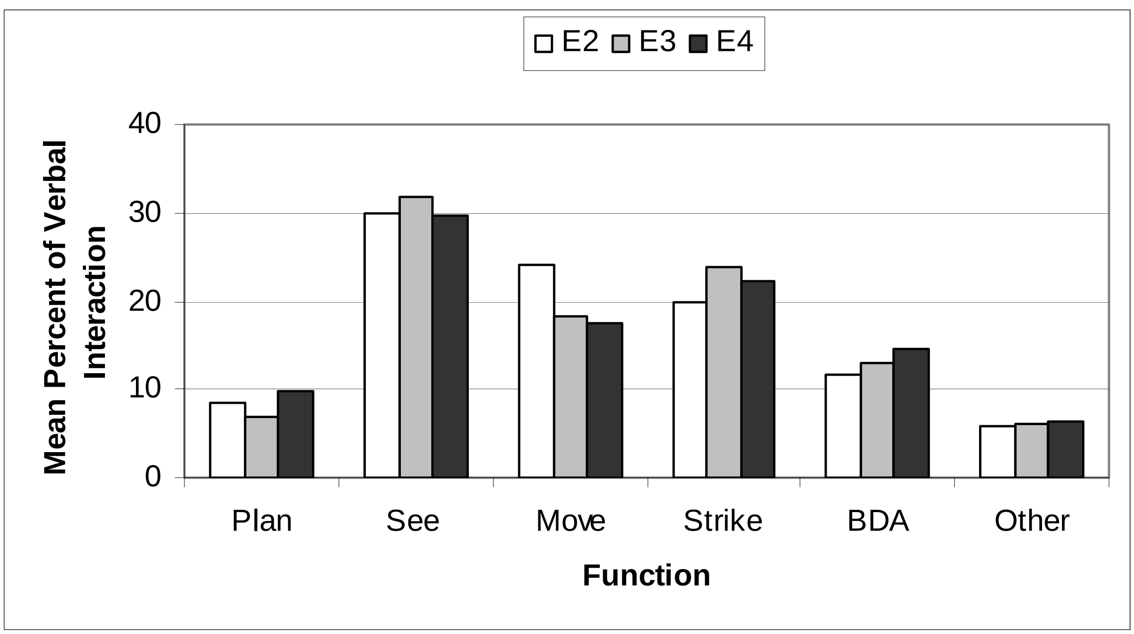



Figure 2. Relative percent of verbal interactions assigned each function code, for one session from each experiment (E2-E4).

The predominance of See reinforces the comments that were made previously about Share. That is, despite all managers having the same CSE system, there was a strong tendency to verbally communicate with one another concerning what was observed.

There appears to be a trend over experiments, for the relative frequency of Move to decrease and the relative frequency of BDA to increase. This may have resulted from continual refinements to the CSE over the course of experiments. Firstly, over the experiments, tasking of unmanned platforms became more reliable, and the tasks that could be assigned to the unmanned platforms more sophisticated (e.g., from each platform needing to be tasked individually to collective tasking such as “group-follow”). Therefore, as the ability to move platforms became increasingly better, the need to talk about platform movement may have decreased. Secondly, as the importance of good BDA data became clear in the operational context, more effort was made by the cell to check on the results of their strikes. In addition, by Experiment 4, some weapons systems were equipped with automatic “Chasers:” sensors that were automatically sent out after a strike, to collect BDA information. Such factors probably led to the gradual increase in the number of interactions concerning BDA. Table 9 gives example chunks for each Function code.

Figure 3 shows the distribution of verbal data over the codes for METT-TC Factor. As can be seen in the figure, the vast majority of verbal chunks were coded as Enemy or Troops. Therefore, these categories are illustrated across their subfactors in Figures 4 and 5, respectively. With regard to the Enemy Factor, the relative frequency of Locate, Identify, and BDA were approximately the same, with discussion of enemy Disposition (probable enemy course of action strategy, or tactics) lower. With regard to the Troops Factor, chunks concerning Strike and

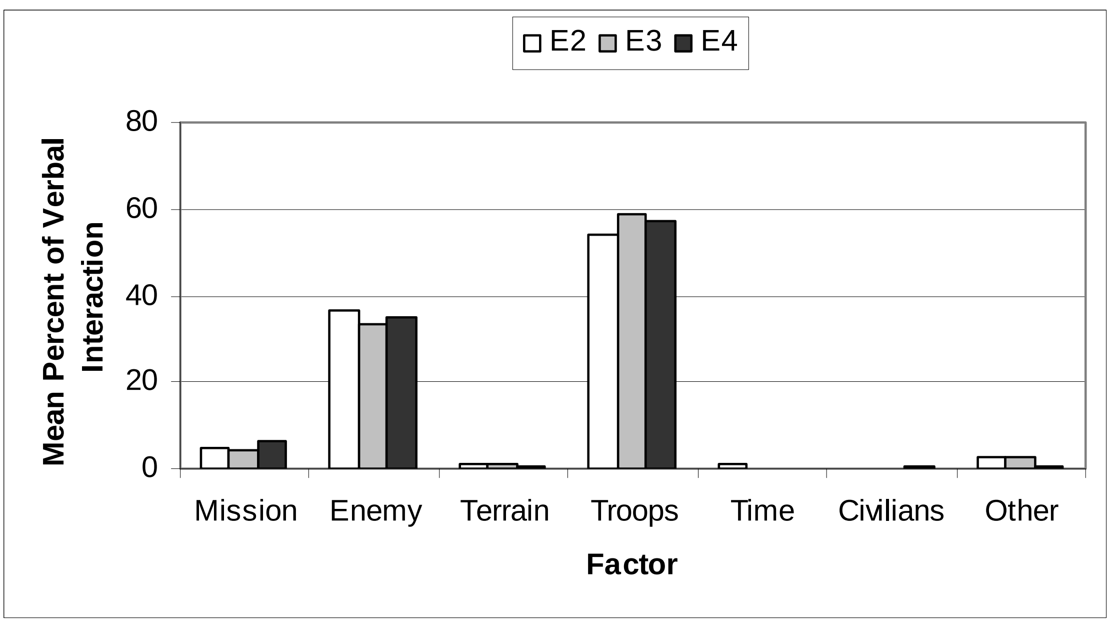



Figure 3. Relative percent of verbal interactions assigned each factor code, for one session from each experiment (E2-E4).

Move predominated, followed by CSE issues, and status reports (e.g., sensors, mobility, position). Other codes were used rather infrequently. Table 10 gives example chunks for the 4 Enemy subfactors. Table 11 gives example chunks for the more frequently used Troops subfactors.

Table 9. Example chunks for each Function code. Note: these are not consecutive chunks

| Speaker | Verbal Data | Function |
|---|---|---|
| | | |
| Commander | Blue6-Black6 | Plan |
| Blue | Blue. Over. | |
| Commander | Alright Blue6-Black6. Initial read of the battlefield is that he is defending forward with a heavy security zone established along the FLOT. Break. I detect at least 2 platoons forward along the FLOT supported by air defense artillery. Break. Additionally, it looks like he's also got some concentration in the center. Therefore I suspect a heavy forward defense, a heavy security zone with a mobile defense more than likely coming from the center sector. Break. Therefore I think I've got all the information I need to begin executing decision point 1 and our attack in the north. Over. | |
| Blue | Roger, I think you'll find more by Granite Pass, on the back side of Iron Triangle. I think we have a good read. Over. | |
| | | |
| Battlespace Manager | That's a series of movers down there. There's wheeled Unknown 24, wheeled H01, MTI… | See |
| | | |
| Commander | OK, C2 Driver | Move |
| Driver | Roger | |
| Commander | I want you to pull over for just a minute. There's a LOS coming behind you. Let the LOS pass you, and then I want you to follow the LOS. How copy? | |
| Driver | Wilco | |
| Commander | Roger | |
| | | |
| Commander | Double tap, I want him double tapped. Brooks, you take him too. | Strike |
| | | |
| Commander | SA-15 smoking, change its state please, gentlemen. | BDA |
| Effects Manager | It's a beautiful thing. | |

Table 10. Example chunks coded as Enemy Factor. Note: these are not consecutive chunks

| Speaker | Verbal Data | Subfactor |
|---|---|---|
| | | |
| Battlespace Manager | Unknown 9, center sector, MTI SAR | Locate |
| | | |
| Effects Manager | What does this look like, Brooksie? | Identify |
| Battlespace Manager | It looks like a Dreaga going up the hill. | |
| Intelligence Manager | Alright | |
| Battlespace Manger | It’s a tracked vehicle | |
| (speaker unknown) | Now he’s staying back | |
| | | |
| Commander | Ok this tells me he is defending forward along the FLOT. | Disposition |
| | | |
| Commander | SA-15 smoking, change its state please, gentlemen. | BDA |
| Effects Manager | It’s a beautiful thing. | |

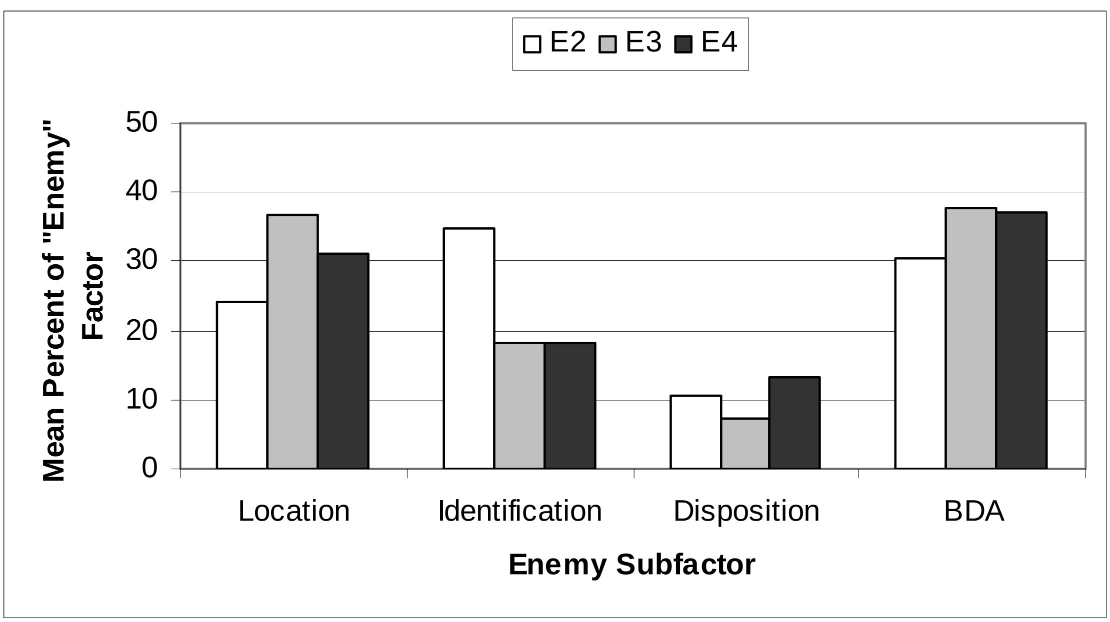



Figure 4. Relative percent of verbal interactions assigned across subcodes of the enemy factor, for one session from each experiment (E2-E4).

Table 11.  Example chunks coded as Troops Factor. Note: these are not consecutive chunks

| Speaker | Verbal Data | Subfactors |
|---|---|---|
| | | |
| Commander | Double tap, I want him double tapped. Brooks, you take him too. | Strike |
| | | |
| Commander | OK, C2 Driver | Move |
| Driver | Roger | |
| Commander | I want you to pull over for just a minute. There's a LOS coming behind you. Let the LOS pass you, and then I want you to follow the LOS. How copy? | |
| Driver | Wilco | |
| Commander | Roger | |
| | | |
| Commander | Hey woah, I've lost my cursor. | IT/CSE |
| | | |
| Intelligence Manager | The resolution is very, very small. And, you know, I don't think I'll be able to see any of this at all. | Sensors |
| | | |
| Commander | Are PAMs going in on all 4 of those targets, David? | Strike Ability |
| Effects Manager | I've still got plenty of PAMs. Don't worry about it. I got it. | |
| | | |
| Commander | Alright, I'm firing two UGS with netfires 1 | Strike Nonlethal |
| | | |
| Battlespace Manager | Everybody else is still healthy and moving | Mobility |
| | | |
| White cell | Black, White, Your push | Caution |
| Commander | Roger, White1 | |
| White cell | Black, Your northern most future warrior carrier receiving artillery fire now. Out. | |
| | | |
| Commander | C2V. Artillery! | Survivability Move |
| Battlespace Manger | C2V. Move back to the east. | |
| Commander | You’ve got to move him. | |
| Battlespace Manager | C2V has got to move with him. | |

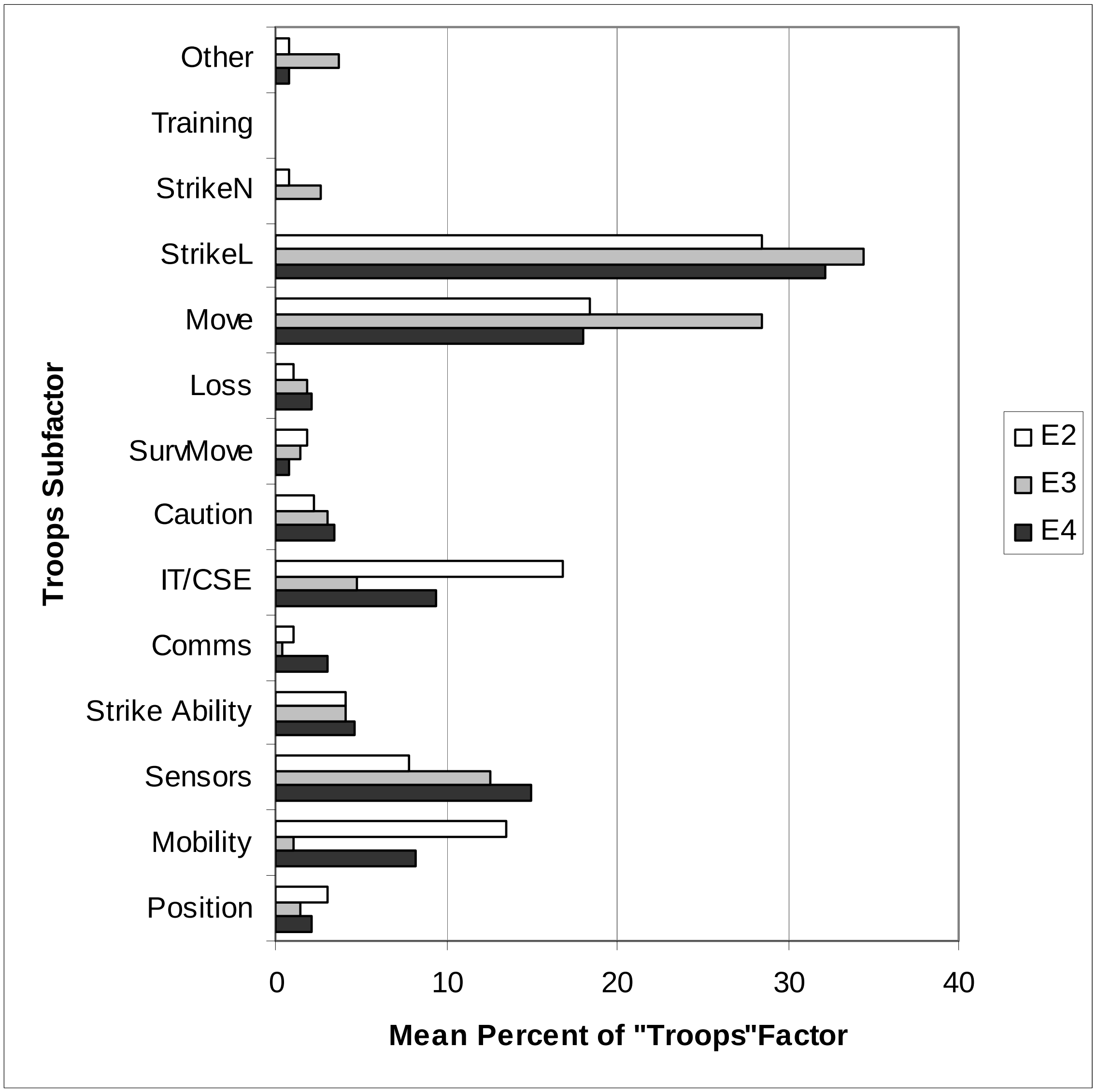



Figure 5. Relative percent of verbal interactions assigned across subfactors of the troops factor, for one session from each experiment (E2-E4). strikeN = strike nonlethal, strikeL = strike lethal, survMove = survivability move, comms = communications.

## Other Approaches Explored

### Systems

Another category, not mentioned above, was used to code the results of Experiment 2. The Systems category consisted of 14 codes relevant to all the friendly force assets, plus three additional categories to cover miscellaneous contingencies in the data. Chunks could receive multiple Systems codes if multiple assets were mentioned in a single chunk. The motivation to include a Systems code was to provide a way to track which assets were discussed most frequently, with the potential to use the data to highlight either the most important or the most troublesome assets. In practice, however, this potential was not fulfilled. The major problem for this category was that speakers often discussed an asset without mentioning it by name. The asset being referred to was implicit based on the context and who was speaking (as certain positions typically controlled particular platforms). In many cases when the asset was not explicitly named, it could be inferred from the context by the coder; however, this was not always the case, and inferences injected increased subjectivity into the coding. As a result, the Systems category was deemed of little practical value, and so was not used in Experiments 3 or 4.

Valence

A perceived shortcoming of the verbal coding scheme was an inability to distinguish diametrically opposed statements. For example, the statements "I can't get it to move" and "He is moving on plan at 30 miles per hour" would receive identical codes based solely on Function and METT-TC categories. While these statements are "about" the same Move function, they convey very different information on the accomplishment of that function. Consequently, a new coding category, Valence, was introduced and used in Experiments 3 and 4 to distinguish communications conveying positive versus negative status on accomplishing $C^2$ functions. The Valence code was always given in relation to the Function code, to signify whether that Function was being carried out successfully or not. Each verbal chunk was scored as negative (–1), neutral/ inconclusive (0), or positive (1) with respect to its coded function. For example, "I can't get it to move" was assigned a negative value (–1); "Is it moving?"(without a verbal response to the question) was assigned a neutral value (0); and "He is moving on plan at 30 miles per hour" was assigned a positive value (1). The valence codes did not address the tactical goodness or appropriateness of the Function, only whether the Function was accomplished. The BDA Function was an exeption; however. BDA verbalizations were scored as negative (–1), if (a) BDA was sought but no useful BDA images were available, or (b) images were available, but the images indicated that the enemy asset still posed a threat. BDA verbalizations were rated positive (1) if there was clear information that the target had been disabled.

Table 12 provides examples of the Valence codes assigned to verbal chunks from Experiment 3 for each C2 function, and Figure 6 illustrates the results of a Function by Valence by session-quartile analysis for a session from Experiment 3. Overall, by far the majority of verbal communications were rated positively in terms of Valence. This pattern of predominantly positive status on accomplishing C2 Functions was found for See, Plan, Move, and Strike related communications. In contrast, BDA and Other related communications were relatively more negative. For BDA, percentage of positive versus negative verbalizations was nearly equivalent. For "Other" communications, particularly technical status comments, communications were predominantly negative. While the Other communications do not directly relate to C2 Functions, they provide useful information on player perceived technical limitations in the C2 prototype (e.g., slow processing and system crashes) that may have undermined the command group's performance across functions.

Negatively valenced communications provide useful diagnostic information on the capabilities of the C2 prototype. Efforts by the FCS C2 program's Technical Team to refine the C2 prototype should attend closely to the problems discussed in negatively rated verbalizations.

For example, Figure 6's quartiles help pinpoint when negative verbalizations occurred in the illustrated session. During quartile 2, player verbalizations indicated problems with Move and BDA functions. These communications stressed the difficulty of controlling the micro-UAVS, which resulted in the loss of two of them. For BDA, negatively valenced communications indicated the participants' inability to kill designated targets. During Quartile 4, negative Move related comments often stressed the inability to maneuver several platforms, including Future Warriors, Robo-Scout, and LOS.

Valence appears to be a useful addition to the coding scheme. Yet it should be noted that it requires interpretation on the part of the coder and can border on the subjective, depending on the chunk content. Note that no attempt has been made to assess inter-coder agreement for the Valence code.

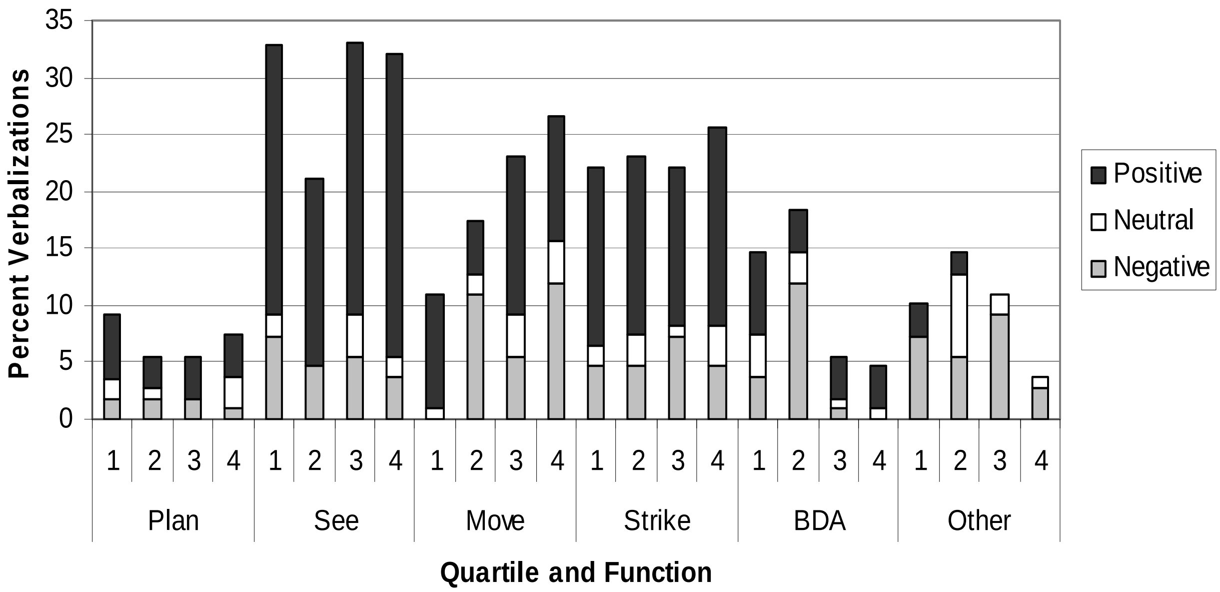



Figure 6. Percent of verbalizations by function, valence, and quartile for one session from experiment 3.

Table 12. Examples of verbal chunks from Experiment 3 by Function with assigned Valence values of positive (1), neutral/inconclusive (0), and negative (-1). Note: bullets indicate multiple speakers

| Function<br><br>Valence | Examples of Verbal Chunks |
|---|---|
| Plan | |
| 1 | • I was just thinking about the birds being too far up there, up North<br>• Bring them South then.<br>• I will, I don't control anything, I've got to ask team to bring them further South. And I can do that, sir, if you don't mind.<br>• No go right ahead, keep them South, that's fine with me |
| 0 | • I got an idea, do you want to try something new?<br>• No |
| -1 | We have unconfirmed as of yet BDA on a tank in the South and a couple of tanks in center sector but we don't have enough intelligence yet to give us a good read of the battlefield other than the fact that he tried to move forward in the center, and I will keep you informed. |
| See | |
| 1 | There's an unknown radio hit. |
| 0 | They haven't fired any artillery yet, have they? (no response) |
| -1 | Dang, there's nothing in my images here. |
| Move | |
| 1 | • So we need to get those 2 micros back down there<br>• They're coming down. |
| 0 | Where is the SAR bird? (no response) |
| -1 | That one's stuck there, number 2 is just not… microUAV 2 is not responding |
| Strike | |
| 1 | • Did you? Did you fire 4?<br>• Yeah, I just fired 4 |
| 0 | Well, the question is, do we reengage? (no response) |
| -1 | OK. Interestingly, you lost comms on the PAMs that you sent. You see that? PAM 54 lost comms. It didn't attack. Hold on a second, the last 2 PAMs that you sent lost comms and did not go to the target. You want me to show you? The one on the Daria did that too. Neither one hit anything. They both lost comms. |
| BDA | |
| 1 | Here is a better image. It looks like it might be perhaps a fire power kill, maybe a fire power, mobility kill. |
| 0 | PAM 16, where did that hit? (no response) |
| -1 | Is it broke? Did we kill it?'<br>I don't know, it doesn't look like it's broke from this image right here, it's hard to tell. |
| Other | |
| 1 | What's the red dot mean?<br>It means that's where it detected something and takes a picture, or that's the place where the Garm was templated. |
| 0 | Blue6, Black 6 (no response) |
| -1 | I've got a right screen frozen. |

Command Considerations

Another coding category used for Experiments 3 and 4 was called Command Considerations. Adding this category attempted to relate participant communications with key cognitive patterns important to battle command. The nine topics used to assess Command Considerations are listed in Table 13, and were based on the research of Lussier, Shadrick, and Prevou (2003). Coding of the verbal data for Command Considerations did not treat the nine codes as exclusive. That is, the same verbal chunk could be assigned multiple command considerations, because as can be seen by reading Table 13, the considerations are not mutually exclusive.

Given that multiple codes could be assigned to one chunk, the data were examined by absolute frequency, rather than the percentage of chunks exhibiting each code. We expected to find evidence for the occurrence of the Command Considerations, given the background and expertise of the participants in the experiments, and indeed we did so, as illustrated in Figure 7. Example verbal data for each Command Consideration is given in Table 14.

Table 13. Command considerations for analyzing command group verbalizations

| Consideration | Description of Consideration |
|---|---|
| Plan | Execution is self-initiated and preceded by plan coordination/refinement. |
| Inform | Make information requirements known. |
| See | Battlefield visualizations that are dynamic/predictive/proactive. |
| Coordinate | Create synergistic effects with multiple assets/teamwork. |
| Assets | Use all assets available. |
| Situation Awareness | Continual situation assessment, dynamic/contingency planning. |
| Terrain/Time | Consider effects of terrain/time. |
| Enemy | Model a thinking enemy. |
| Mission | Keep sight of the big picture and mission intent. |

It was hypothesized that Command Considerations could be a useful measure when comparing teams of different levels of expertise, and in particular as a measure of leader development and/or battle command expertise. Gordon (2001) found a difference in the number of cognitive statements made by experienced vs. inexperienced Air Force weapons directors in a simulated task environment. We compared the behaviors of the experts who participated in Experiments 1-4 against a group of West Point Cadets and ROTC students who participated in a separate experiment (between Experiments 2 and 3). As the novice players used a CSE similar to that used by the experts for Experiment 2, the data from one expert session from Experiment 2 (deemed most similar in mission to that given the novices) was analyzed and compared to the novice's data. A report detailing the results of that analysis is in preparation (Carnahan, Lickteig, Sanders, and Durlach, in preparation). Here are presented just the results for Command Considerations (see Figure 8). It is clear from inspection of Figure 8, the novices produced less frequent evidence for Command Considerations. It should be noted, however, that the single coder who assigned Command Considerations was not blind to which group (experts vs. novices) was being coded. Further, no attempt was made to assess inter-coder agreement. The coder (first author) who assigned the codes felt the assignments were very subjective, and that further development and definition of the code elements is required. Finally, it should be noted that for both groups, Command Considerations amounted to less than three percent of verbalizations.

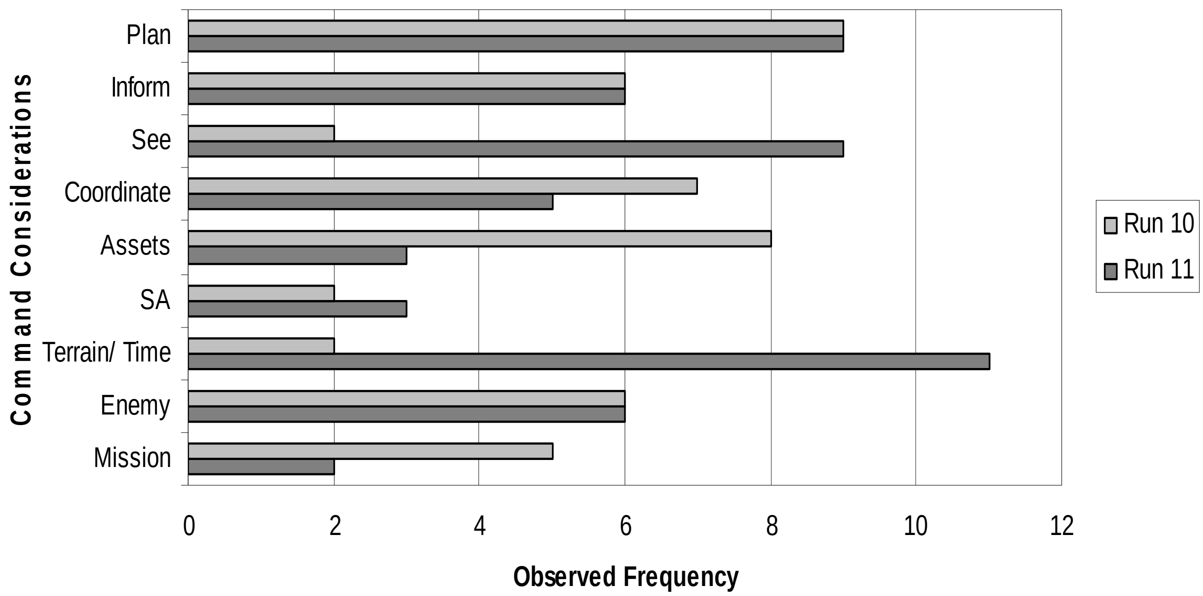



Figure 7. Frequency of command considerations for 2 sessions from experiment 3. Note: Command considerations defined in Table 13. SA = situation awareness.

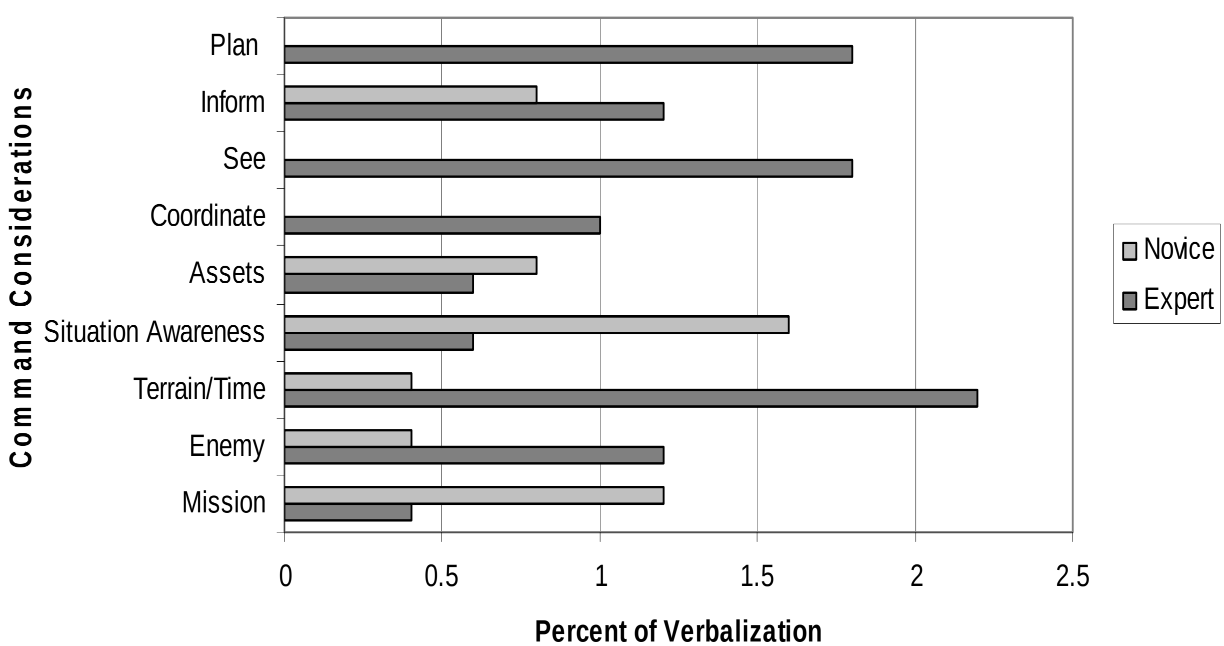



Figure 8. Percent of verbalizations counted as a command consideration, comparing observations for the expert vs. the novice participants. Note: Command considerations defined in Table 13.

Table 14. Examples of Verbal Communications by Command Considerations from Experiment 3

| Consideration | Example |
|---|---|
| Keep sight of the big picture and mission intent. | I think they are probably dead, or mobility kills which for this scenario is both good. |
| | Yeah. |
| | We won't waste any more rounds on him. |
| | Yeah. Actually, just as long as we hit him even if they are fire power kills, I don't care less. |
| | Jack, what we don't want to do is get into the Netfires. |
| | Yeah exactly, exactly. |
| | So that’s why I'll leave the troop transport there, to protect our flank. |
| | Protect the flank |
| Model a thinking enemy. | That means he is moving out of sector. |
| | I mean they dropped it right on top of him. |
| | Either that or he is trying to reposition from where they told us he was at Start Ex. |
| | That could very well be. |
| | Right in the middle of the valley, back to a ridgeline, or forward into the gap there. |
| Consider effects of terrain/time. | I'm just looking, I'm trying to find that freaking keyhole up in here. |
| Continual situational assessment and dynamic/contingency planning. | I stopped, go to the heads up. I stopped him, that's his eyes so if this guy continues in this direction that's a keyhole. And if he ends up here I ought to be able to see him and that would be within Javelin range. |
| | Okay. |
| | If he pops up in any of these areas here. |
| Use all assets available. | Brooks, I don't think we are going to get the A160 any time soon, so I need you “Sir” to get the GSR up on some higher ground there right in front of you and get a mast up. |

Table 14 continued on next page.

| Table 14 continued. | |
|---|---|
| Create synergistic effects with multiple assets/teamwork. | Hey Jack, head's up chief, here's my second IFV team in the South. |
| | Okay. |
| | It runs… |
| | Now that tank. |
| | Yeah we got to kill him.  He dies first. |
| | But he runs here, this is pretty much covering the meadow this point right here is where he stops…infantry North. |
| | But this time, all hell is going to break loose. |
| | All of a sudden two different infantry teams are popping up on the ridge, well one on the ridge and one on the road, but they are only 300m apart. All of a sudden he's got clear visibility across the valley. |
| | Very nice, now which one, that's the IFV. |
| | That's the IFV with 2 mounted teams. |
| | Okay. |
| | Now I've got the dismounts starting off, 2 routes, this guy is here, he moves here, and all of a sudden… |
| | That's a pretty good view. |
| | He gets a good view out of the valley. This bobo down here. He is going to move down this route, and he should be able to, shortly, acquire anything out in that open area there, at this position. See where that is open? |
| | Oh yeah. |
| | So that's right now his route plan. |
| | For dismounts? |
| | Yeah. |
| Battlefield visualizations that are dynamic/ predictive/proactive. | Hey Dave, if I was a guessing man, I would say that radio link 3, which is up there where that PAM lost comms, has now become unknown 27. I'm just telling you, I think that very well may have moved that down there. |
| Make information requirements known. | I want to see in front of us with those Micro-UAVs, it takes a long time to try to develop what's in front of us, so we need to do that as quickly as possible. |
| Execution is self-initiated and preceded by plan refinement/coordination. | No other detections, Micro-UAVs going out there taking pictures. |
| | Go micro go. |
| | Got one back here.  Micro 1 waiting for its detections up there in the North, to go and take pictures there.  The other 3 are out on the route. |

Analysis of Planning Phases

As mentioned previously, each experimental mission was preceded by a planning phase during which the participants planned their mission, based in part on an intelligence report (which was different for each session). Observation by ARI at the experimental site indicated that key C2 functions were taking place during these planning sessions. Consequently, ARI arranged to capture the verbal interactions of Experiments 3 and 4 during the planning as well as the mission execution phase of each session. Verbal interactions during Experiments 3 and 4 planning phases were analyzed in the same manner previously described for the mission execution phases of Experiments 3 and 4. Fidelity of the verbal recordings was lower than during execution, however, due to participants neglecting to use their headsets continuously during planning phases. In addition, it was observed that some planning discussions took place outside, as well as within, the $C^2$ vehicle simulator. Consequently, not all verbal interactions related to planning were captured for analysis.

Table 15 gives some of the characteristics of the planning phases analyzed, and as can be seen in the table, planning phases were typically shorter than mission execution sessions, with consequently fewer verbal chunks. The percent of time spent verbalizing during planning was less than during mission execution. Possible explanations for less verbal interaction during planning are that not all participants remained in the $C^2$ vehicle during the entire planning phase, and their headsets were not continuously worn even when they were present. It was also observed that participants spent more time working individually with the CSE, entering duty-specific mission and planning data (e.g., routes and tasks) into their computers.

Table 15. Key characteristics of 3 analyzed planning phases

| Session | Experiment 3, Run 10 | Experiment 3, Run11 | Experiment 4, Run.8 |
|---|---|---|---|
| Session Duration | 56 minutes | 39 minutes | 51.75 minutes |
| Cumulative Silence* | 7.6 minutes | 10.1 minutes | 7.5 minutes |
| # Verbal Chunks | 75 | 61 | 62 |

* Timing initiated after 3 seconds of silence

As there were less than one fourth the chunks for each planning phase than for most mission execution sessions, more variability in the relative distributions of verbal behavior over the codes should be expected, and was observed. Mean data across the 3 planning phases, therefore, will be presented, and compared with the average of the mission execution data presented above. Table 16 shows these data for the Source category. As during execution, during planning, the vast majority of verbal interactions occurred among the Black cell members. There was a bit more communication with Blue and Other (possibly technicians), and less with subordinates (who often were not present during the planning phase).

Figure 9 compares planning and execution verbalizations categorized according to the Type of interactions that occurred. Whereas Share interactions predominated during execution, in planning, it was Ask interactions that were most prevalent. The relative frequency of Action also was greater than during execution. These data comply with casual observations that during planning, the participants were more likely to report to one another what they were doing as they were doing it, and to check with one another, as might be expected during planning.

Figure 10 compares planning and execution verbalizations categorized according to Function addressed in the verbal interactions. Hardly surprising, during planning, Plan was the most frequently observed Function. Other was the second most frequent Function; this reflects the participants' tendency to talk socially and less formally during the planning phase.

Table 16. Mean percent of verbal interaction observed for each code of Source category

| Source code | Planning | Execution |
|---|---|---|
| Within Black Cell | 78.3 | 84.9 |
| Black - Subordinates | 3.0 | 7.2 |
| Black - Blue | 11.0 | 4.5 |
| Black - White | 0.0 | 0.3 |
| Blue - White | 0.0 | 0.4 |
| 3-way | 0.0 | 0.1 |
| Other | 7.3 | 2.6 |

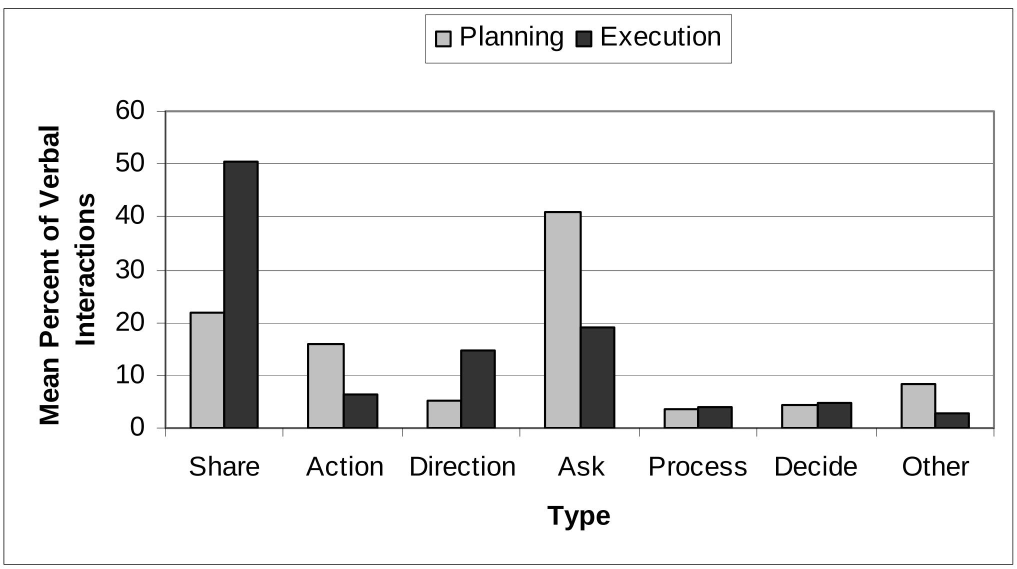



Figure 9. Comparison of the average relative distributions of the type category for planning vs. execution phases for sessions from experiments 2-4.


Figure 10. Comparison of the average relative distributions of the Function category for planning vs. execution phases.

Figure 11 compares planning and execution verbalizations categorized according to METT-TC. Instead of being almost totally concerned with Enemy and Troops, as during execution, during planning, interactions were spread more evenly among the 7 METT-TC codes. Although Troops still predominated, during planning, interactions coded as Mission were the second most frequent, followed by Enemy.

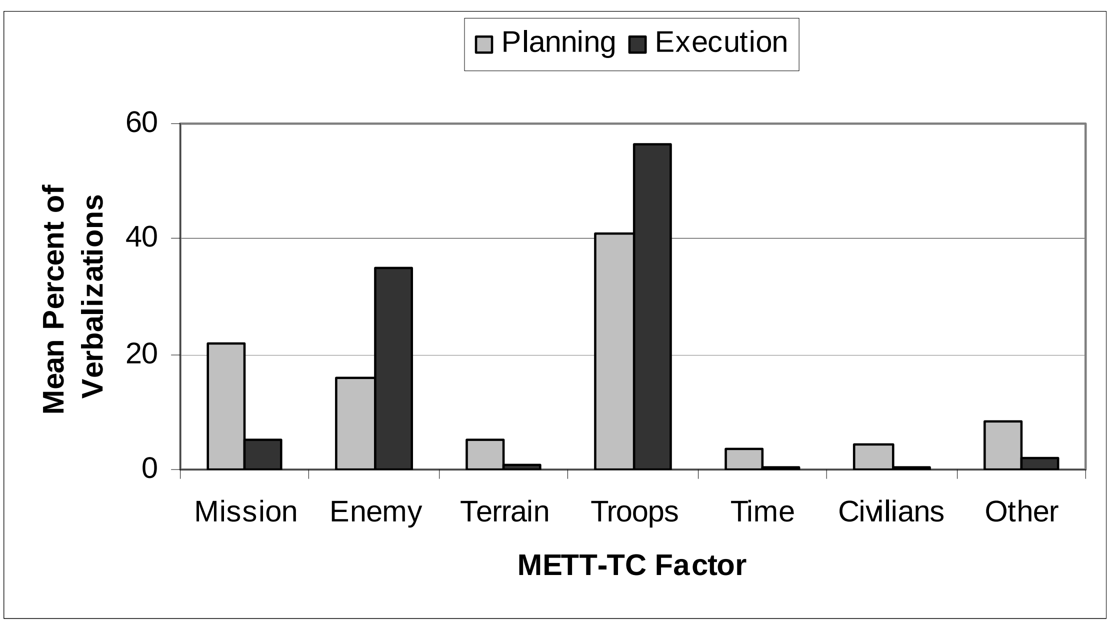



Figure 11. Comparison of the average relative distributions of the factor category for planning vs. execution phases.

The results from analysis of the planning phases appear to differ from the results of analysis of the mission execution sessions of these experiments. This indicates that a different pattern of interaction occurred during planning as compared with execution. It also indicates that the coding scheme was able to detect this difference. It should be cautioned, however, that the coder was not blind to whether a session undergoing coding was from planning or from execution.

With respect to C2 performance, planning behaviors are fundamental. The way a team performs during mission planning can have a significant effect on their mission situation later. A crew that conducts thorough planning and considers alternative contingencies may be less apt to make hasty responses or to lose a common operating picture during the mission.

Code Combinations

An additional approach to using the coding scheme could be to examine code patterns across categories. By examining various code combinations, it would be possible to answer specific questions, should they arise. For example, one could examine the Type by Source interaction to see if particular Types of interactions were more prevalent among certain cells in the experiment (see Lickteig, Sanders, Durlach, and Carnahan, 2002 for an example).

For Experiments 2 (and 3) we examined "code profiles." That is, the 3-way combinations of Source-Type-Factor. For the 3 execution sessions analyzed from Experiment 2, 198 Source-Type-Factor profiles were used; but interestingly 13 profiles accounted for 50% of the data. If we only had these 13 profiles, we still could have coded half of the data of Experiment 2. All of these 13 profiles were coded as Within-Cell for Source. The other combinations of Type and Factor are listed in Table 17, along with the percent of the data each

Table 17. 13 code profiles accounting for 50% of the chunks of the data analyzed for Experiment 2. All these were interactions among the black cell members

| Type | Factor | % of all chunks |
|---|---|---|
| Share | Locate enemy | 7.7 |
| Share | IT/CSE | 6.4 |
| Direction | Strike-Lethal | 5.5 |
| Share | BDA | 4.4 |
| Share | Identify Enemy | 3.7 |
| Process | Enemy Disposition | 3.1 |
| Share | Mobility Report | 3.1 |
| Action | Strike-Lethal | 3.5 |
| Ask | Strike-Lethal | 3.5 |
| Share | Strike Status | 2.9 |
| Share | Sensor Status | 2.7 |
| Ask | Locate Enemy | 2.4 |
| Share | Strike-Lethal | 2.2 |
| Cumulative Total | | 51.1 |

profile accounted for. One could consider whether some of the most frequent profiles could be supported by automated support systems, in particular, the ones sharing new information observed from the CSE. For example, Share-Locate enemy or Identify enemy: the CSE could verbally announce relevant information when new enemy icon appears on the situation awareness map.

## Discussion of the Coding Scheme Used for Experiments 2-4.

The coding scheme applied to the verbal data of Experiments 2-4 was useful in providing quantitative measures describing the verbal behavior of the experimental participants. Moreover, the scheme was sensitive enough to reveal different patterns of verbal interaction during mission execution vs. mission planning, and different patterns for a novice vs. a more experienced team. Despite these accomplishments, there are several ways in which the coding approach could be improved.

Firstly, the chunking issue was never fully resolved. Transcripts were chunked first by Type. Then on a second pass through the data, any chunks for which multiple other codes seemed to apply were further subdivided. There were no clear rules for this latter subdivision; and no attempt was made to assess whether different researchers agreed or disagreed with the way it was carried out. The second pass through infused knowledge of the coding scheme itself into the chunking, which ideally would be completely independent of the coding scheme subsequently applied to it. Breaking the text down into smaller chunks made it easier to apply the coding scheme. On the other hand, it meant that certain interactions concerning higher level cognitive processes were broken down into several chunks, with the consequent loss of the ability to capture those cognitive processes in code (see Yang, 2003 for further discussion of this problem). This is one reason the new category, Command Considerations was introduced for Experiment 3. However, that category contains codes that are quite vague and subjective, and reworking them into a more objective instrument would be useful.

For the analysis of Experiment 2 data, efforts were made to establish the objectivity of the coding scheme by assessing inter-coder agreement. To maintain the scientific integrity of the data, it is recommended that multiple coders and the assessment of their agreement always be an element of the coding process. The coding is a cognitively demanding activity, especially selecting one of the 25 METT-TC subfactors. As a matter of human nature, the coder is apt to adopt various habits or biases to reduce cognitive load. Awareness that code assignments will be compared to those of another coder aids in preventing criteria shifting during coding. Measurement of inter-coder agreement also provides some kind of index regarding the objectivity of the coding scheme (Ericsson and Simon, 1993).

It is anticipated that in the future, the verbal coding scheme may be used to compare the behavior of different groups of participants, or the same participants under varying conditions. Should this be the case, it is recommended that coders be blind to the nature of the groups or conditions while conducting coding. As with assessing inter-coder agreement, blind coding will help maintain the scientific integrity of the findings. For certain types of comparisons, this may be difficult, despite the best of intentions, however. The actual content of the transcripts may provide hints as to the nature of the data collection conditions. In addition, knowledge of the context in which the data were produced may be fundamental to understanding transcript content (see Yang, 2003 for a discussion of this point).

The coding scheme is quite complex and contains several redundancies. In particular, the separate categories of Function and Factor, contain substantial overlap. This results in both extra work for the coder, more data to be processed and presented, and more complexity for the end user of the data. Ideally, Function should emerge from subsets of different Factor codes, and not be a separate coding category in and of itself. Below, a revised coding scheme that attempts to do this is presented.

Neither the above, nor the revised scheme presented below, are hypothesis driven. The schemes were developed largely on the basis of doctrinal tradition (e.g. METT-TC), and the results generated may not necessarily be significant in addressing insightful questions about the differences between operations in today's army and the Furture force. Specific hypothesis driven analyses may require further code refinement or the addition of new coding categories.

## A Revised Coding Approach to Factor

As a result of the short-comings of the coding scheme, described above, an attempt was made to modify the scheme subsequent to Experiment 4. One goal of the revision was to streamline the scheme to make it easier to apply and present. Focus was placed on the Function, Factor, and Command Considerations categories. It is recommended that application and revision of other coding categories should be governed by hypotheses and research goals. For example, if one research goal were to investigate patterns of communication within the Unit Cell, Source could be modified to identify specific individuals participating in the interactions.

The Factor category, as before, was based on METT-TC. It consisted of 23 codes, as listed in Table 18. The intention was to compose a list of clearly defined topics that would fit into the METT-TC framework, eliminate codes from the original scheme that were never or very rarely used, and eliminate redundancy and ambiguity. Towards the goal of eliminating redundancy, instead of coding separately for Function, as before, the intention was to derive Function (and/or Command Considerations) from the Factor codes. Our proposed method of associating Factor codes with these higher order categorizations is illustrated in Table 18.

Another goal of the revision was to capture higher level cognitive processes within the context of the Factor category. Within the revised scheme, we assert, the Plan Function captures the intention of what we sought with Command Considerations. For the original scheme, the requirement to assign one and only one code to each chunk of data meant that the chunks had to be relatively short. Consequently, more abstract concepts that were discussed could only be perceived by reading several consecutive chunks, and were not captured by the Factor category. For the revised scheme, we changed the chunking rules and allowed coders to assign as many Factor codes to a chunk as they deemed appropriate. Text was chunked on the basis of natural communication. That is, one chunk ended and another began when there was a natural break in the conversation. This still does introduce an element of subjectivity, in that a coder still does need to decide where these breaks are. However, at least the chunks are created independent of

Table 18. Factor Category codes for the revised scheme and their association with Function

| **Code** | **Factor** | **Code Definition** | **Function** |
|---|---|---|---|
| 1 | Mission | Focus on mission intent | Plan |
| 2 | Mission | Make mission critical information requirements known | Plan |
| 3 | Mission | Make responsibilities known/delegation/role clarification. | Plan |
| 4 | Mission | Maintain common operating picture (situation report or integration/summary of current situation or interpretation of situation; create common understanding; NOT mere citing of enemy targets or status of a system) | Plan |
| 5 | Mission | Create synergistic effects with multiple assets/teamwork and/or use all assets available | Plan |
| 6 | Mission | Create or modify friendly plan/COA, based on current intelligence (proactive) | Plan |
| 7 | Mission | Contingency planning: proactively consider events that may require change of plan, and/or prepare alternative responses accordingly | Plan |
| 8 | Mission | Other (concerning Mission, but none of the above, include mission rehearsal here) | Plan |
| 9 | Enemy | Locate enemy positions, movement, or identify nature of enemy target | See |
| 10 | Enemy | BDA: discuss sensor feedback (including eyes) on damage inflicted on enemy | BDA |
| 11 | Enemy | Model a thinking enemy, generate probable enemy COA, strategy, tactics | Plan |
| 12 | Enemy | Other (concerning enemy, but none of the above, e.g., if enemy has been shot at and by who or what) | See |
| 13 | Terrain | Consider effects of terrain | Plan |
| 14 | Troops | Mobility status report | Move |
| 15 | Troops | Status report: any other status report or assessment of friendly element status including workload, weapon used in previous strike, weapon supply, loss of asset, communications, or other functionality | See |
| 16 | Troops | Information processing system: functioning of the CSE and use of head's up display | See |
| 17 | Troops | Immediate Danger: Awareness of immediate dangers, and hasty reactions taken to avoid them, such as a survivability move | See |
| 18 | Troops | Move: deliberate tasking/management/maneuvering of platforms (or nonlethal effects) | Move |
| 19 | Troops | Strike: Launch/fire/deploy lethal or potentially lethal effects (present or future), including order to fire in reaction to sighting enemy target. | Strike |
| 20 | Troops | Other (e.g., training, anything concerning friendlies that is not covered in 8-18) | See |
| 21 | Time | Consider time constraints or timing coordination | Plan |
| 22 | Civilians | Any issues concerning civilians / noncombatants | Plan |
| 23 | Other | Other (anything else not covered by mission, enemy, terrain, time, troops, or civilians, can include joking around, other non-mission related interactions, or uninterpretable interactions.) | Other |

the coding scheme itself. In addition, relaxation of the constraint of one and only one code per chunk meant that all content could be coded regardless of the precise method of chunking. Indeed, it could be argued that with this relaxation, no chunking is required at all. The codes could be applied to a continuous stream of verbal interaction. Nevertheless, we elected to use chunking. Having discrete chunks was useful for purposes of data analysis. Without some way of associating codes with particular sections of text, there would be no way to accurately assess inter-coder agreement.

One reason for originally allowing one and only one code per chunk was that it followed the dictates of classic protocol analysis (Ericsson and Simon, 1993) and made data analysis relatively straight forward. In contrast, if coders are free to assign as many codes as relevant to each chunk, analysis of the data becomes considerably more complex. For summarizing such data, one approach is to factor in the total number of codes assigned. Thus, a summary descriptive statistic for each code element could be: Percent of verbalizations for code X = Number of Verbalizations coded as X / Number of codes assigned to the transcript. Notice that this summary statistic is independent of the number of chunks in a transcript. Note, however, that chunking does still have consequences. Under the revised scheme, a chunk that has repeated instances of the same subfactor (e.g., multiple sightings of the enemy), would be assigned that code only once (indicating it occurred in the chunk, but not how frequently); were the same piece of text divided into multiple chunks, that code might be assigned multiple times. On the other hand, this will partially be offset by calculating the percent of verbalizations on total number of codes assigned.

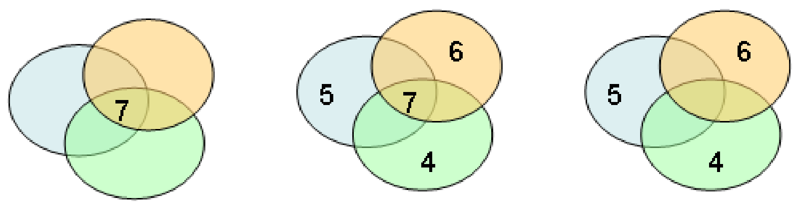
According to the previous scheme (each chunk gets one and only one code), computation of inter-coder reliability was relatively straight forward; however, it was not clear what to do with the data for a chunk on which coders disagreed. Which code was correct? With the revised approach, disagreement among coders is allowed, and in a sense, adds to the richness of the data, for it allows for multiple interpretations. If one thinks of the summary percentages as probabilities, then each time a coder assigns a particular code, it raises the probability that a particular topic was being discussed. If, for a certain piece of text, all coders agree, the probability is higher than if each assigns a different code. By pooling all coders' results, and dividing by the total number of codes assigned (by all coders), codes for which there is more agreement will be represented as higher probabilities. Codes for which there is less agreement will not be discarded, but rather will be represented as smaller probabilities. Thus, high probabilities imply both frequent use of a code and inter-coder agreement. Lower probabilities are ambiguous, however; they could imply either low frequency with high agreement, or high frequency with low agreement (that is, coders use the code often, but don't agree on the chunks to which it is assigned). Thus it is necessary to introduce some measures of agreement.

We used two measures of agreement: one to assess inter-coder agreement (do different coders assign the same codes to chunks?), and one to assess code consistency (level of agreement among coders for each particular code). Both of these computations do require the use of chunks, or at least some way to designate which piece of text has been assigned which codes by each coder. For inter-coder reliability we used a measure that varies between -1 and 1, such that 1 indicates perfect agreement among coders and -1 complete disagreement among coders. 0 indicates equal amounts of agreement and disagreement. The equation used to compute inter-coder agreement is given in Figure 12.  A value for agreement is computed for each chunk, and then the scores are averaged to yield a mean agreement among coders, for each transcript.

For 3 independent coders:

$$\text{Inter-coder AGREEMENT for each chunk} = \frac{(\#\text{ doubles} \times 2) + (\#\text{ triples} \times 3) - \#\text{ singles}}{\text{total }\#\text{ codes assigned}}$$

Where # triples = # of codes used by all 3 coders
# doubles = # of codes used by 2 of the coders
# singles = # of codes used by only 1 of the coders




| AGREEMENT = | 1 | 0 | -1 |
|---|---|---|---|
| | All 3 coders assign a code of 7 to a chunk. | All 3 coders assign a code of 7 to a chunk; but each also assigns another code on which they disagree (4,5, 6). | All 3 coders assign a different code to the same chunk. |

Figure 12. Explanation and illustration of the measures of agreement suggested for evaluating the revised coding scheme.  Then Venn diagrams depict 3 possible coding outcomes, with each of 3 coders represented by one of the circles in each diagram.

An analogous measure was computed for code consistency.  Instead of computing a measure of agreement for each chunk, a value is computed for each code, by examining the agreement concerning which chunks the code was applied to.  This measure can be used to interpret the relative percentage at which a code was assigned, which, as mentioned above, can be ambiguous.  An intermediate percentage with a high code consistency implies a low frequency with consistent assignment of the code across coders, whereas the same percentage with a low code consistency implies a high frequency, but inconsistent use of the code across coders.

There are various ways in which inter-coder agreement and code consistency could be computed.  One feature to note regarding the measure we chose is that it penalizes more for disagreements of commission (assigning a code that none of the other coders used), than for omission (not assigning a code that the other coders used).  In particular, a value of 1 can be obtained if all coders assign exactly the same codes, but also, if there is a discrepancy only of omission (e.g., one coder assigns codes 4,5,6, another assigns 4,5, and a third assigns 5,6).

## Application of Revised Factor Codes

Two graduate students from the University of Central Florida (report co-authors) served as coders, in addition to the first author. They had no previous expertise in the FCS domain, except for helping to transcribe the audio data from some of these experiments into written transcripts. During preliminary meetings, the first author reviewed the features and terminology of the FCS experiments, and a revised Factor coding scheme. Randomly selected chunks were examined and the codes appropriate for each were discussed. On the basis of these discussions, the code definitions were further refined to eliminate ambiguity. Independently, each coder then coded 30 consecutive chunks of text from Experiment 4; and the coders subsequently met once again to discuss their code assignments, and further questions or ambiguities. This process continued until all coders were satisfied that we had reached a common understanding of the coding scheme, and sufficiently clear code definitions. This took five iterations. Thereafter, coding of a new session was conducted and the student coders were advised to seek interpretation from the first author on any parts of transcripts they had difficulty understanding; the interpretation provided explained the meaning of the text, without reference to the coding scheme itself.

### Analysis of Mission Execution

After coder training, one execution session from Experiment 3 was re-chunked and independently coded by the three coders. The new chunking approach resulted in 236 chunks (compared with 461 from the original scheme), and the 3 coders applied 1407 codes (an average of about 2 codes per chunk, per coder).

Figure 13 illustrates the relative frequency of the METT-TC factors using the revised coding scheme. For comparison, the results for the same session using the original coding scheme are also shown. As can be see in the figure, the relative distributions for the revised and original schemes were essentially identical. One difference was a relatively higher proportion of Mission factor verbalizations coded under the revised scheme.

Figure 14 illustrates the Functions derived from the revised Factor coding. For comparison, the results for the same session using the original coding scheme are also shown. As can be seen in the figure, See was the most frequently observed function for both schemes; however, the difference between See and the next most frequently observed function was greater for the revised scheme (53.9 vs. 17.4) than for the original scheme (31.7 vs. 23.9). Moreover, in the revised scheme, the second most frequently observed function was Plan, as opposed to the original scheme, for which both Strike and Move were relatively more frequent than Plan. This most likely reflects the revision of the coding scheme to better capture command considerations and other aspects of planning that were difficult to capture in the original scheme.

Figures 15, 16, and 17 illustrate how the METT-TC codes were distributed across specific subfactors. Subfactors contributing to the function Plan are illustrated in Figure 15. Those associated with the function See are illustrated in Figure 16, and the remaining subfactors (associated with Move, Strike, and BDA) are illustrated in Figure 17. The number in parentheses

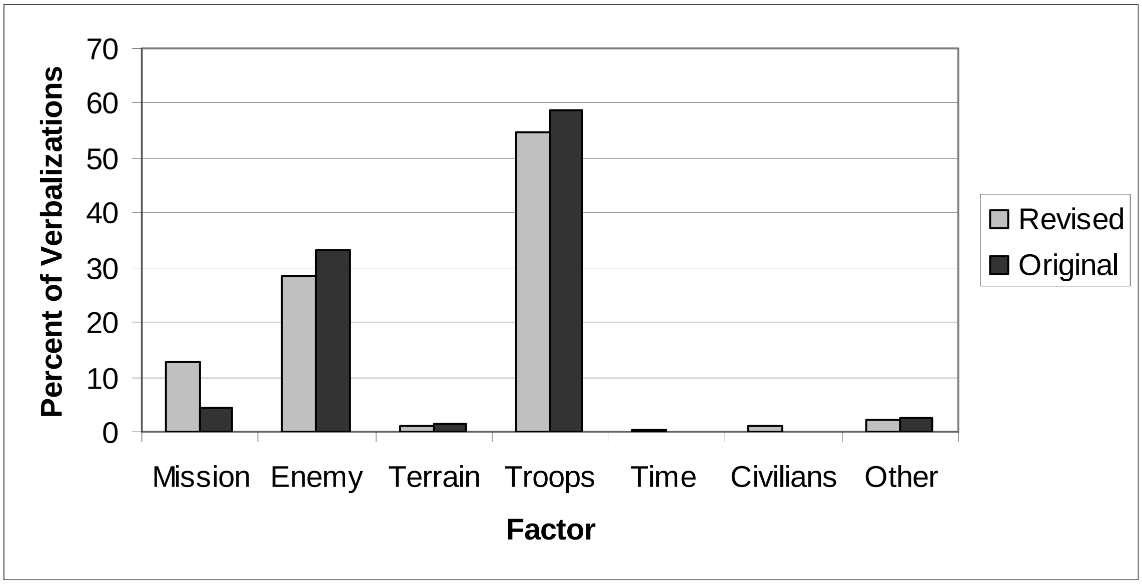



Figure 13. Relative frequency of the METT-TC factors for an execution session, for the revised vs. the original factor schemes.

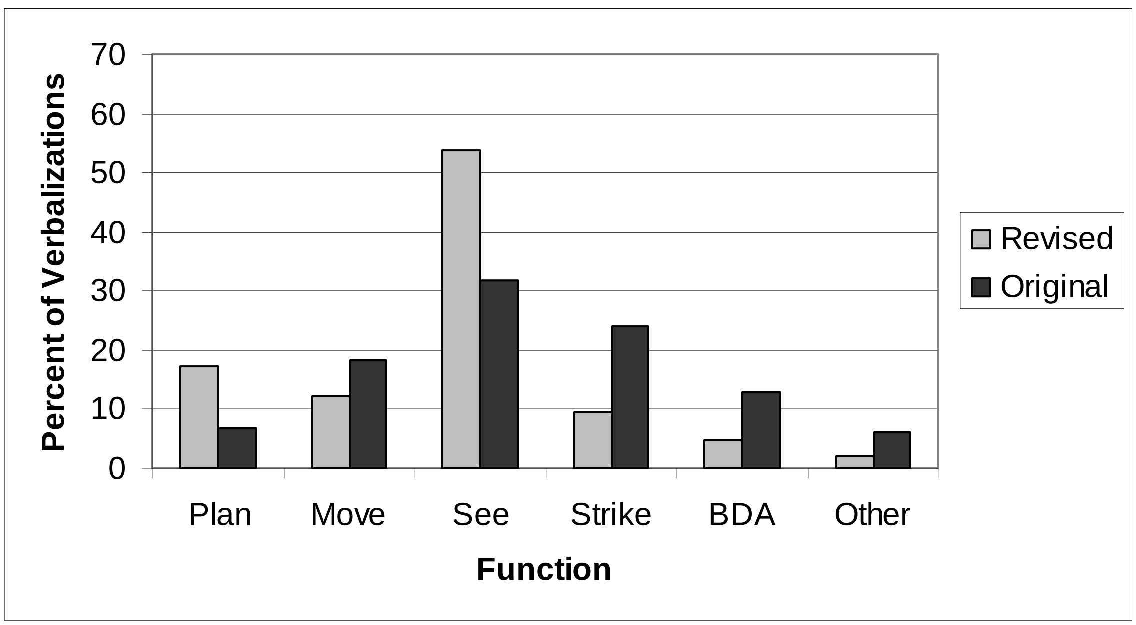



Figure 14. Relative frequency of the function categories for an execution session, for the revised vs. the original coding schemes.

above each bar in these figures represents code consistency (for each code, the degree to which coders agreed in its use). These numbers are also shown in Table 19, along with the number of observations for each code (the more observations made for each code, the more confidence one can have that the measure is meaningful).

Figure 15 shows that Delegation was the most frequently observed Plan subfactor, and that it had a relatively high code consistency of .42. On the other hand, except for Civilians, the code consistency of the other subfactors was rather lower than we would have liked. These subfactors were the most abstract and therefore required the most interpretation on the part of the coders. Thus, achieving code use consistency for these may be a perpetual challenge. However, for some cases, we feel better agreement could be achieved with more coding training and practice. For example, the two student coders were biased against using Time or Terrain (this came out in subsequent discussion). For other cases, the codes were used so rarely that the measure derived for code consistency is probably not very meaningful (e.g., Mission Focus was only used one time by one coder, resulting in a consistency score of -1).

Figure 16 shows the subfactors associated with function See. For these subfactors, code consistency was relatively good, ranging from .34 to .70. The most frequent of the subfactors associated with See were status reports, followed by enemy locations/identifications. Figure 17 shows the subfactors associated with Move (Mobility and Move Action), Strike, and BDA. As for the See subfactors, code consistency for these was fairly good, ranging from .52 to .71.

Figure 18 illustrates the distribution of scores for inter-coder agreement across chunks. For each chunk, a measure of inter-coder agreement was computed as described in Figure 12. As can be seen in Figure 18, the coders agreed more than they disagreed (agreement >0) about 90% of the time.

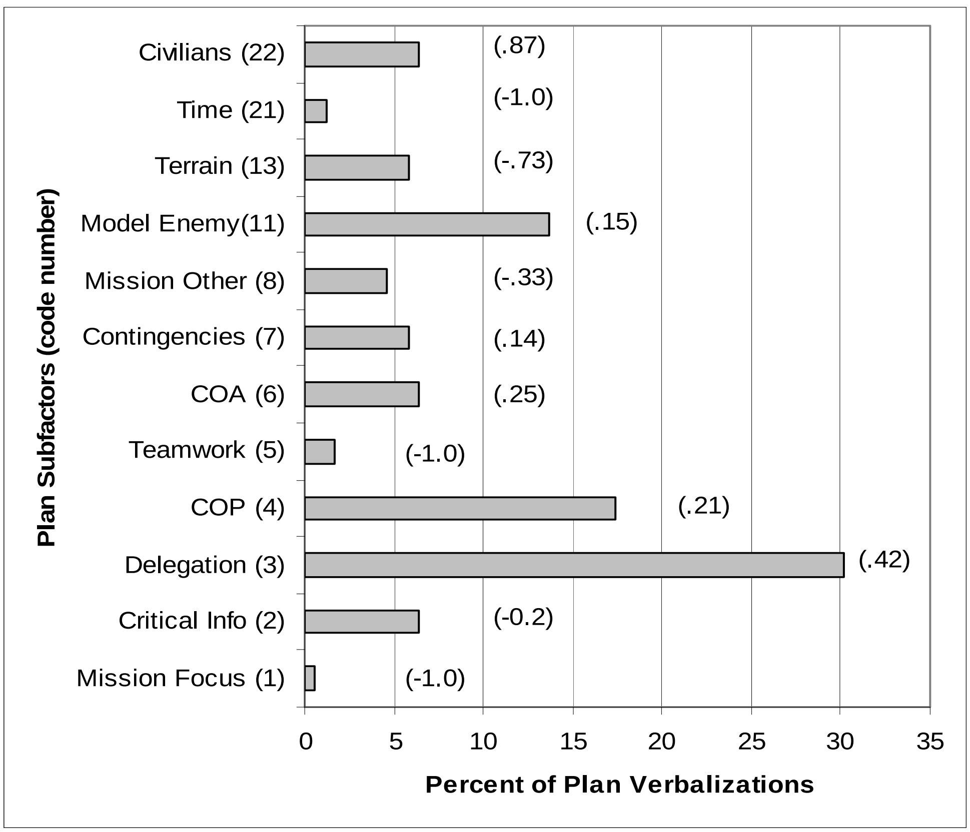



Figure 15. Relative frequency of the subfactors associated with the function Plan, when the revised coding scheme was applied to a mission execution session.

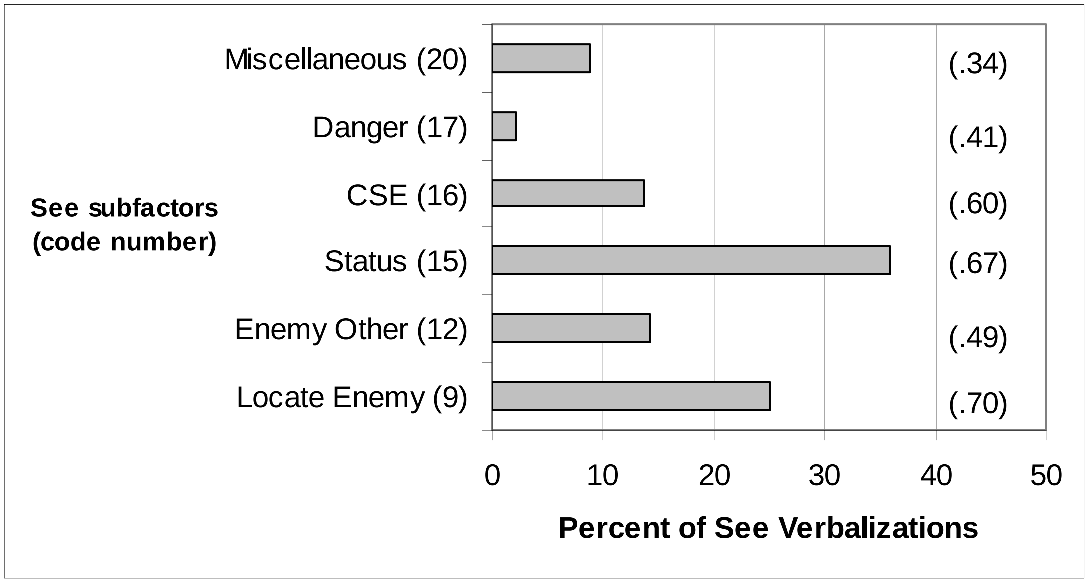



Figure 16. Relative frequency of the subfactors associated with the function see, when the revised coding scheme was applied to a mission execution session.

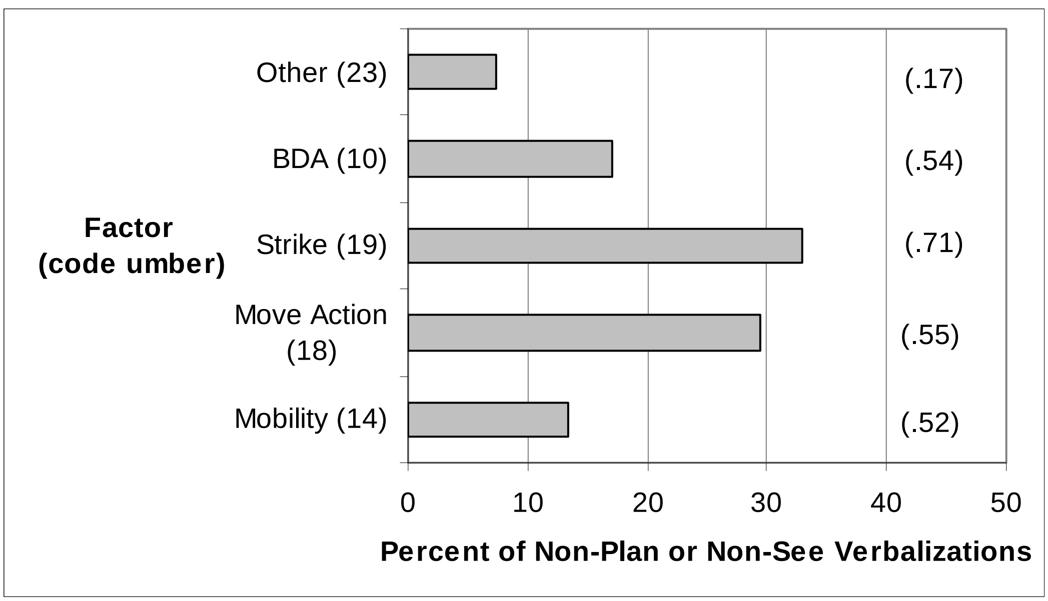



Figure 17. Relative frequency of the subfactors not associated with plan or see, when revised coding scheme was applied to an execution session.

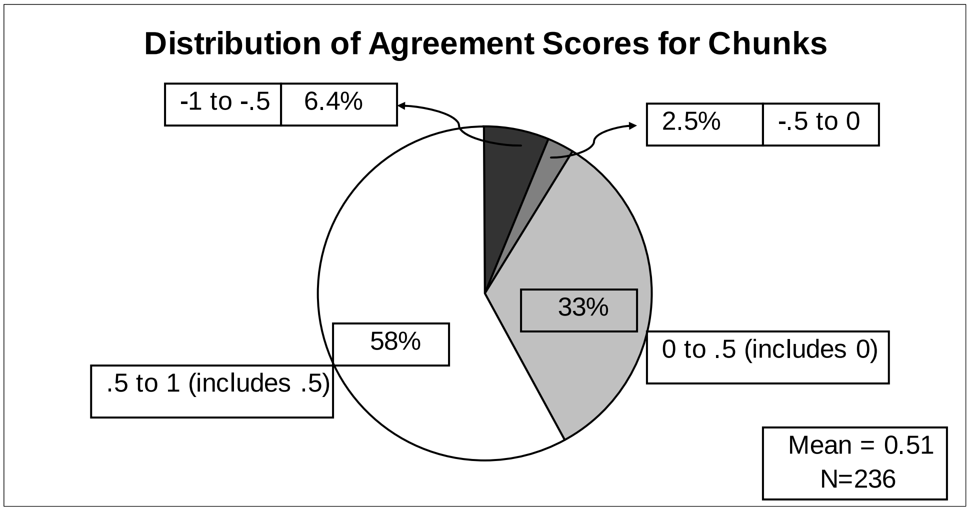



Figure 18. Distribution of inter-coder agreement scores when the revised scheme was applied to an execution session. Each of the 236 chunks was assigned an inter-coder agreement score. scores could range from -1.0 (complete disagreement) to 1.0 (complete agreement).

Analysis of Planning Phase

To further assess the appropriateness of the revised coding approach, we also applied it to one planning session from Experiment 4. Rechunking produced 63 chunks. 237 codes were assigned by the three coders, for an average of about 1.5 codes per chunk, per coder. Figure 19 illustrates the obtained relative frequency of the METT-TC factors, as well as the results for the same session using the original coding scheme, for sake of comparison. As can be see in the figure, the relative distributions for the revised and original schemes were similar, except that under the revised scheme, Troops was relatively less frequent and Other was relatively more frequent, than for the original scheme. This was largely due to the fact that many verbalizations that had been coded as Troops-Other (code 20, Table 4) under the original scheme, were coded as Other (code 23, Table 18) under the revised scheme.

Figure 20 illustrates the same data, but now categorized by Function. The results were similar for the original and revised coding schemes, except for the relative frequencies of See and Strike, with See being more frequently coded, and Strike less frequently coded, under the revised as compared with the original scheme. For those relatively frequently coded functions, Plan and See, the results are further broken down by code in Figures 21 (Plan) and 22 (See).

For Plan (Figure 21), Mission-Other was the relatively most frequently coded topic. The subfactor included mission rehearsal, as well as other interactions that were mission-relevant, but not well captured by the other subfactors. Code consistency was generally better for these subfactors for the planning session, than for the execution session (see Table 19 for a direct comparison); despite the fact that there were less data. This may be because planning interactions during planning sessions may be more obviously about planning (e.g., due to use of future tense, or explicit discussion of “the plan”), than such interactions during execution. It may also be due to the coders’ knowledge that they were coding a planning session; having that knowledge they may have been more prone to use planning-associated codes (however, coders were not explicitly aware of which codes contributed to function Plan while coding, as this was derived later and not represented on the coding plan).

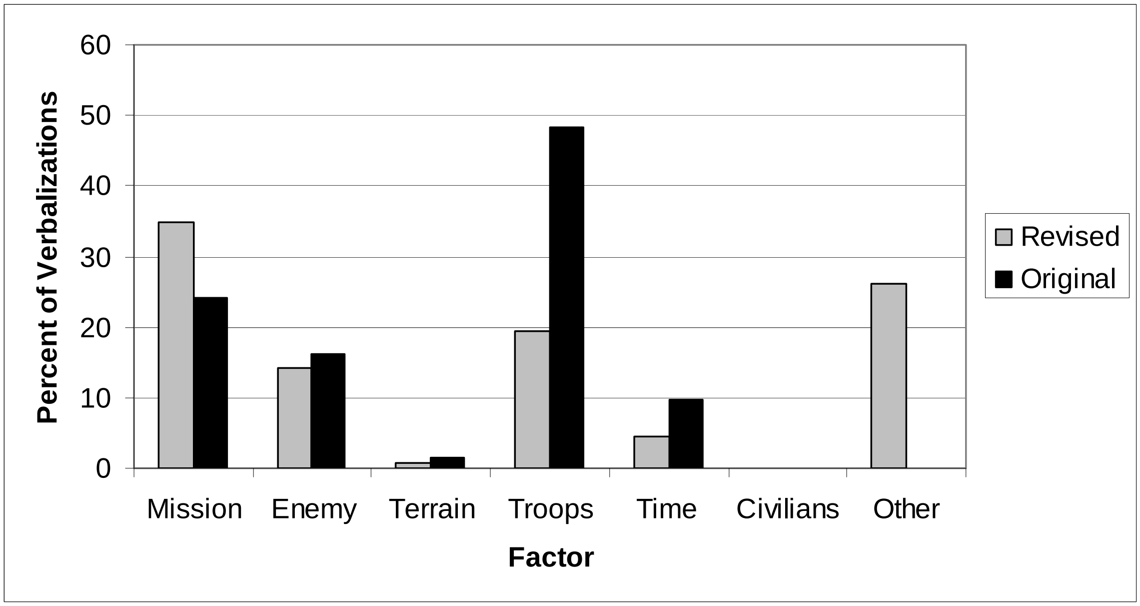



Figure 19. Relative frequency of the METT-TC factors for a planning session, for the revised vs. the original factor schemes.

For See (Figure 22), Locate enemy was relatively more frequent than any of the other associated codes, and had a fairly good level of consistency (.68). The other codes associated with See had a poor level of consistency for planning (less than 0).

Figure 23 illustrates the distribution of inter-coder agreement scores across the 63 chunks. Agreement was fairly good, with a mean score of 0.41, despite the fact that there were relatively few chunks. Eighty-seven percent of the scores were 0 or greater.

Table 19 lists code consistency for the execution and planning sessions, in order to allow an examination of how these varied from one session to another. In actuality, there is probably not enough data here to determine whether certain codes are used more consistently than others. Further refinement of the coding scheme could entail application of it to more data, with an attempt to assess and further revise codes that coders seem unable to use consistently. Of course, other forms of assessment are also possible, for example examination of intra-coder reliability (same coder coding the same transcript multiple times).

Table 19. Code consistency scores associated with each of the 23 Factor subcodes of the revised coding scheme, for an execution session, and a planning session. Numbers in parentheses give the actual number of times that code was assigned by the coders

| **Code** | **Factor** | **Code shorthand** | **Function** | **Consistency Execution (#observations)** | **Consistency Planning (#observations)** |
|---|---|---|---|---|---|
| 1 | Mission | Mission Focus | Plan | -1.0 (1) | 1.0 (3) |
| 2 | Mission | Critical Information | Plan | -0.20 (15) | -0.33 (6) |
| 3 | Mission | Delegation | Plan | 0.43 (73) | 0.65 (17) |
| 4 | Mission | Common Operating Picture | Plan | 0.21 (43) | -0.12 (16) |
| 5 | Mission | Teamwork | Plan | -1.0 (5) | -0.33 (6) |
| 6 | Mission | Course of Action | Plan | 0.25 (16) | 0.38 (16) |
| 7 | Mission | Contingencies | Plan | -0.14 (14) | 0.67 (6) |
| 8 | Mission | Mission Other | Plan | -0.33 (12) | 0.13 (30) |
| 9 | Enemy | Locate enemy | See | 0.70 (189) | 0.68 (25) |
| 10 | Enemy | BDA | BDA | 0.54 (69) | 1.0 (3) |
| 11 | Enemy | Model Enemy | Plan | 0.15 (33) | 0.20 (10) |
| 12 | Enemy | Enemy Other | See | 0.49 (107) | -1.0 (3) |
| 13 | Terrain | Terrain | Plan | -0.73 (15) | -1.0 (2) |
| 14 | Troops | Mobility | Move | 0.52 (54) | -- (0) |
| 15 | Troops | Status | See | 0.67 (270) | -0.29 (17) |
| 16 | Troops | CSE | See | 0.60 (109) | -0.05 (19) |
| 17 | Troops | Danger | See | 0.41 (17) | -- (0) |
| 18 | Troops | Move Action | Move | 0.54 (119) | -0.11 (9) |
| 19 | Troops | Strike | Strike | 0.71 (132) | -1.0 (1) |
| 20 | Troops | Miscellaneous | See | 0.34 (67) | -0.60 (10) |
| 21 | Time | Time | Plan | -1.0 (3) | 0.85 (13) |
| 22 | Civilians | Civilians | Plan | .87 (15) | -- (0) |
| 23 | Other | Other | Other | .17 (29) | 0.87 (75) |

A comparison of Figures 14 and 20 reveals that the revised scheme produces different relative distributions over Function for planning and mission execution phases. Likewise, a comparison of Figures 13 and 19, shows this is also true for METT-TC Factor. Thus, the revised scheme still seems to discriminate the two phases.

## Conclusions

The present report described the evolution of a coding scheme for verbal interactions in an FCS C2 setting. The work was exploratory in that coding was intended to characterize the verbal interactions observed, but was not aimed at testing any particular hypothesis. We suggest that the revised coding scheme presented and illustrated in the latter sections is of potential use for future hypothesis-driven research in the FCS C2 arena. The METT-TC Factor coding scheme could be used in conjunction with other coding categories prescribed by the research question, to provide a quantitative analysis of verbal interactions. The advantages of the revised

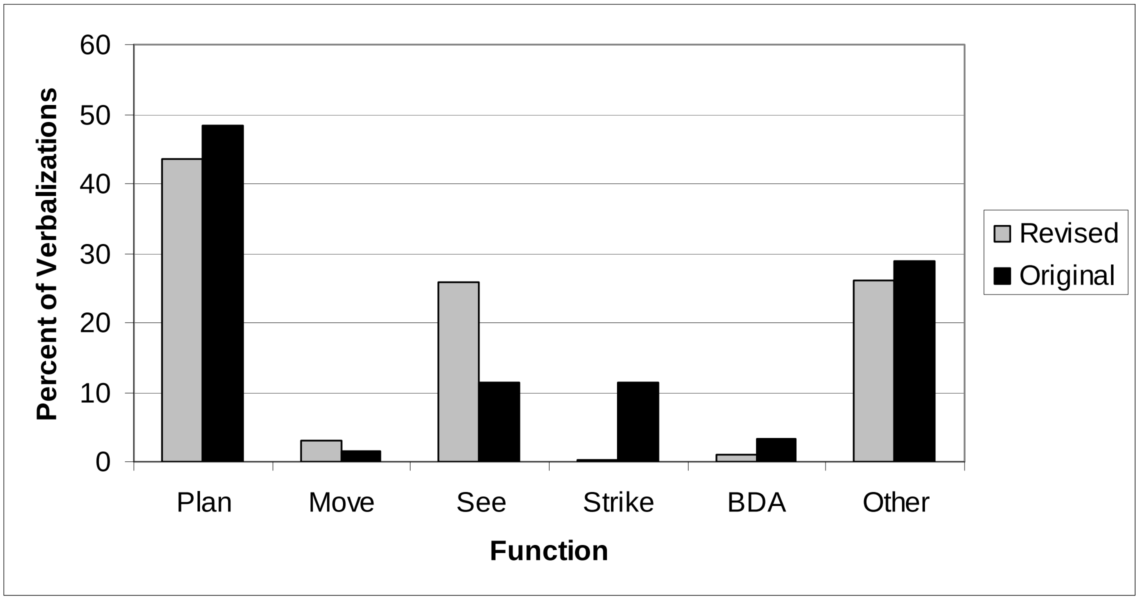



Figure 20. Relative frequency of the function categories for a planning session, for the revised vs. the original coding schemes.

Factor coding scheme are that it allows room for interpretation (coders are allowed to disagree), and captures concrete as well as more abstract conversational content relevant to C2. The former could also be seen as a disadvantage, however; as it is not clear how much disagreement should be acceptable before the scheme is deemed unreliable. Only for a large number of respondents (coders), are there techniques (multivariate) for handling such uncertainty. Another disadvantage is that the data analysis is somewhat more complex, compared with the one chunk – one code approach.

The effort and time involved in analyzing the data, on the other hand, pales in comparison to the effort and time involved in transcribing the audio recordings of the verbal interactions into written transcripts. This task is required for any coding scheme and should always be taken into consideration when deciding whether to conduct a verbal analysis to begin with. The second most intensive task is training the coders. This is particularly the case when coders have little familiarity with the content to be coded, and need to learn subject matter and specialized terminology. When this is the case, it is hard to determine if inconsistent usage of codes across coders is due to differences in interpretation or merely lack of understanding. In the ideal, the coding scheme would be applied by subject matter experts. Despite efforts to be "objective," analysis of verbal data such as that discussed here always has an element of interpretation (Yang, 2003). In particular, coding of the more abstract verbal elements (e.g., model a thinking enemy) was less consistent, than coding of more concrete verbal elements (e.g., command to strike). This may be a perpetual problem even with extensive training of coders. We suggest that, beyond refining the coding scheme, and training coders, the only way to get a handle on this "subjectivity" is to measure it, and interpret the data in the light of the information. If the code is applied to experimental data (i.e., data collected under systematically varying conditions), it is essential that coders be blind to those conditions, for the results to be as objective as possible.

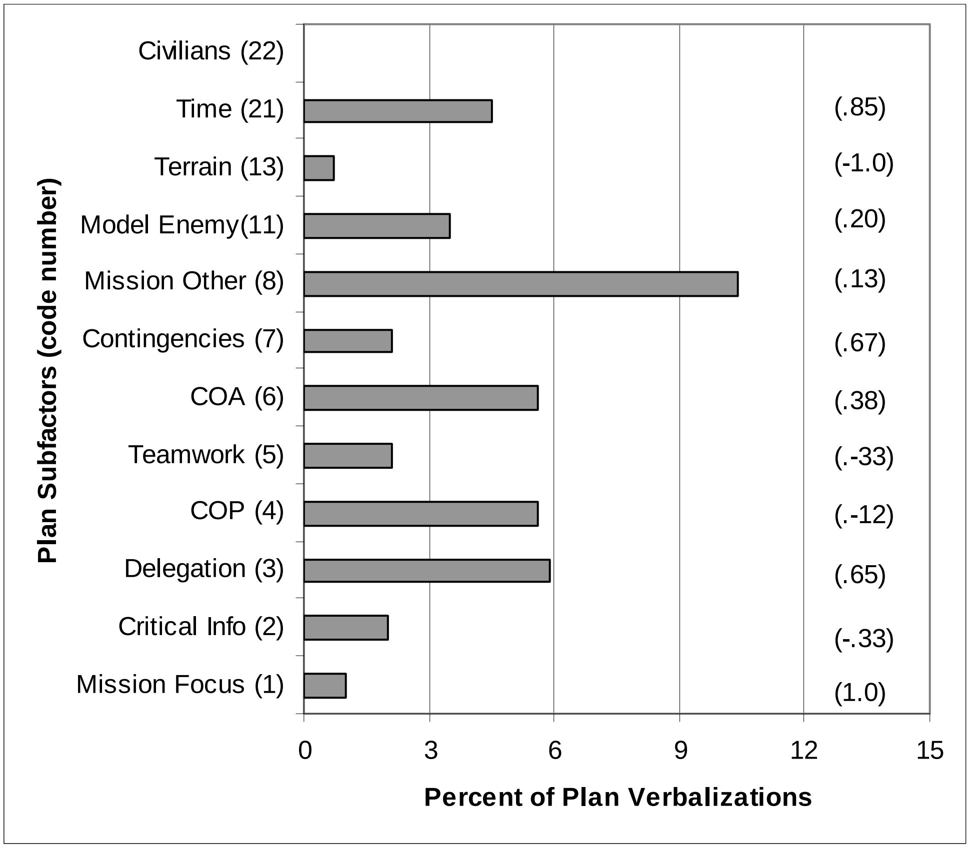



Figure 21. Relative frequency of the subfactors associated with the function plan, when the revised coding scheme was applied to a planning session.

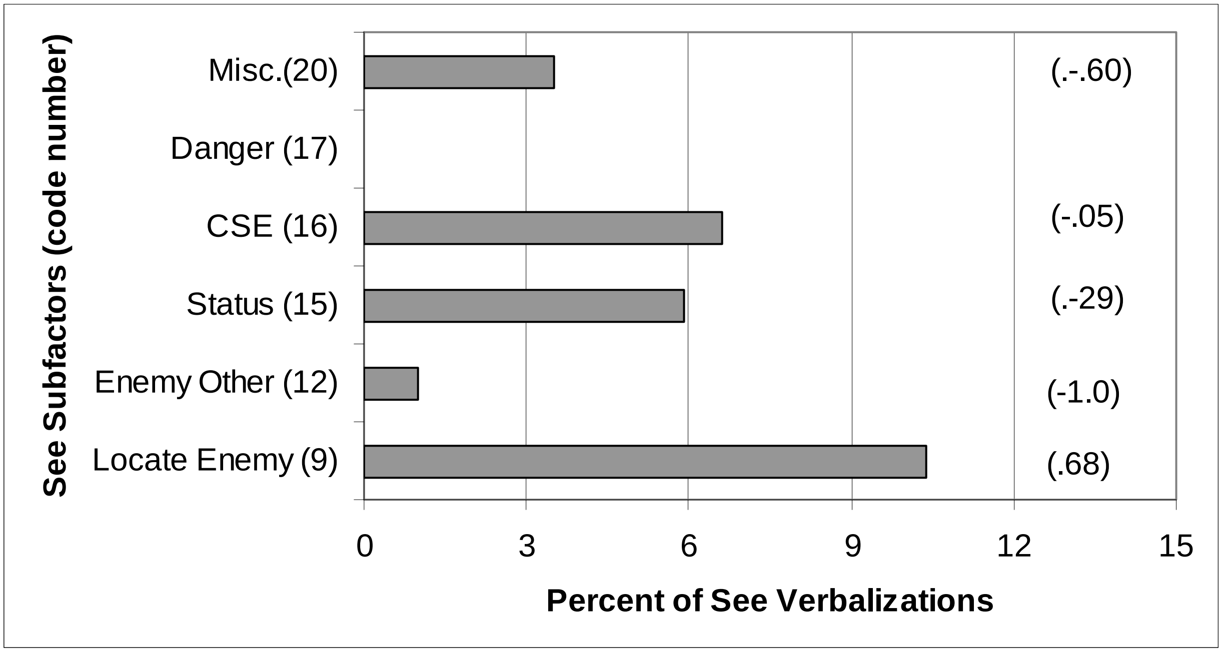



Figure 22. Relative frequency of the subfactors associated with the function see, when the revised coding scheme was applied to a planning session.

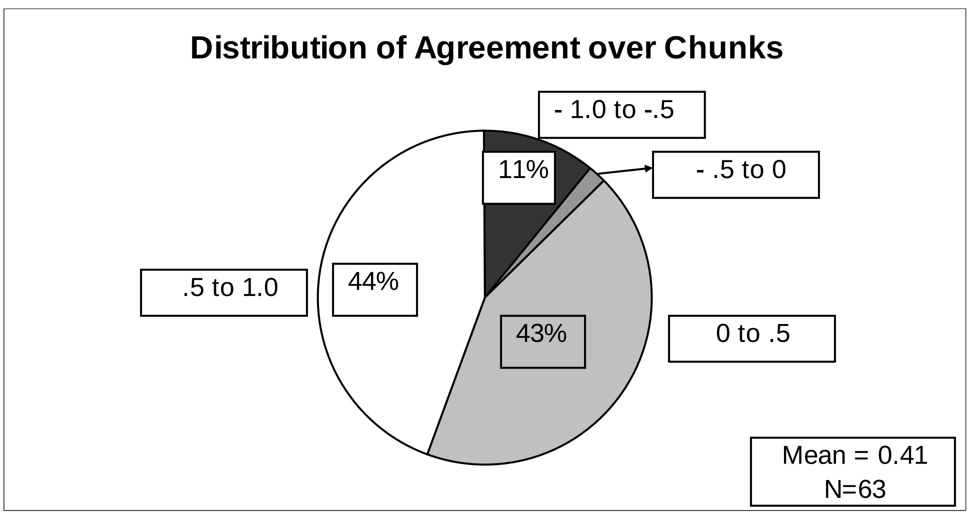



Figure 23. Distribution of inter-coder agreement scores when the revised scheme was applied to a planning session. Each of the 63 chunks was assigned an inter-coder agreement score. Scores could range from -1.0 (complete disagreement) to 1.0 (complete agreement).

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ACRONYMS

| | |
|---|---|
| AGM | Attack Guidance Matrix |
| ARI | Army Research Institute |
| BDA | Battle Damage Assessment |
| C2 | Command and Control |
| C4ISR | Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance |
| CECOM | Communications-Electronics Command |
| comms | communications |
| CSE | Commander’s Support Environment |
| DARPA | Defense Advanced Research Projects Agency |
| FCS | Future Combat System (of systems) |
| FLOT | Forward Line of Troops |
| FWC | Future Warrior Carrier |
| IFV | Infantry Field Vehicle (same as FWC) |
| LAM | Loitering Aerial Munitioin |
| LOS | Line of Sight |
| MTI | Moving Track Indicator |
| mUAV | Micro UAV |
| NLOS | Non-Line of Sight |
| OTB | One-SAF Testbed |
| PAM | Precision Aerial Munition |
| RDEC | Research and Development Center |
| ROTC | Reserve Officer Training Corp |
| SAF | Semi-Automated Forces |
| SAR | Synthetic Aperture Radar |
| STO | Science and Technology Objective |
| UAV | Unmanned Aerial Vehicle |
| UGS | Unattended Ground Sensor |

SAMPLE UNCHUNKED AND UNCODED TRANSCRIPT, EXPERIMENT 4, SESSION 8, 03/03.

| | |
|---|---|
| Commander | Let us turn on the AGM please. Execute the AGM please. |
| Effects | AGM executed. |
| Commander | Roger |
| Commander | And there goes the AGM. |
| Effects | Beautiful! |
| Commander | I did not see the SA in the south. I guess he's targeted, the SA-15. |
| Battlespace Manager | He's been targeted. |
| Commander | And Roger |
| Effects | Hold on. I have threat manager up? |
| Effects. | SA15, MPERM |
| | MPERM |
| Battlespace Manager | It's been fired. |
| Commander | Right, and Roger |
| | Should be waiting for our chaser. |
| Commander | And, Roger. |
| | There's the chaser. |
| Commander | Now look Ken, I want you to ask higher to help you in the south and you concentrate on the north. |
| Commander | Higher's pulling up those pictures? |
| Intel Manager | Higher's working on the south and deep. |
| Commander | Alright gentlemen, . |
| Intel Manager | And I'm focused on the center. |
| Commander | Good. |
| Intel Manager | I'm going to focus on the route. |
| Commander | SA-15 smoking, change its state please, gentlemen. |
| Effects | It's a beautiful thing. |
| Commander | Oh, hey, you've got something smoking next to it too. That chaser, head's up. |
| Intel Commander | Yes |
| Commander | Watch this. The chaser that's just north of it, looks like a smoking Dreaga, not a scout team. Am I wrong? |
| Intel Commander | What chaser is that? |
| Commander | Chaser 2, not chaser 1. |
| Battlespace Manager | Radio unknown 6. |
| Commander | It looks to me like a Dreaga, gentlemen. What do you say Ken? You're the man. |
| Intel Manager | I would say that's a  Dreaga. I would say that's a smoking Dreaga. |
| Commander | I think it's a smoking Dreaga. |
| Commander | I'll change it, I'll change it. |
| Intel Manager | And a URALs truck is smoking too. Chaser 4. |
| Effects | Truck killer, truck killer. |
| Battlespace Manager | You gonna change that, Ken? |
| Intel Manager | I'll change it. |
| Battlespace Manager | Ok, you've got a chaser 7. |
| Intel Manager | I changed it. |
| Battlespace Manager | Looking at chaser 7. Yes baby, yes. |
| Battlespace Manager | Looky here on the heads up. |

| | |
|---|---|
| Commander | Quick fires, net fires launcher. |
| Battlespace Manager | How's that for chaser, Jack? |
| Commander | Oh very nice. Change state please. We'll take that one. |
| Effects | It appears to be a Dreaga. |
| Commander | It appears to be a Dreaga. Ok this tells me he is defending forward along the FLOT. And now which chaser was that, sir? |
| Battlespace Manager | That was chaser 7. |
| Commander | Tell me it was 7, it was 7? |
| Battlespace Manager | Yes |
| Commander | That's all I wanted to know, ok, good, I got it. |
| Commander | And Blue6-Black6. |
| Blue | Blue6.Over. |
| Commander | Alright Blue6, Black6. Initial read of the battlefield is that he is defending forward with a heavy security zone established along the FLOT. Break. |
| Commander | I detect at least 2 platoons forward along the FLOT supported by air defense artillery. Break. |
| Commander | Additionally, it looks like he's also got some concentration in the center. |
| Commander | Therefore I suspect a heavy forward defense, a heavy security zone with a mobile defense more than likely coming from the center sector. Break. |
| Commander | Therefore I think I've got all the information I need to begin executing decision point 1 and our attack in the north. Over. |
| Blue | Roger, I think you'll find ... by Granite Pass, on the back side of Iron Triangle. I think we have a good read. Over. |
| Commander | Ok, what I need now, is I need you to switch… have you painted everything with the A160? Over. |
| Blue | Roger, we are in the process of covering the box. Over. |
| Commander | Ok we need to switch in just a minute and go SAR. Over. |
| Intel Manager | Yeah, if they can do T1… |
| Commander | In fact if you can do T1, we are ready for that now. Over. |
| Commander | Blue-Black, did you copy last? |
| Blue | I'm going to check that now. |
| Commander | Thank you sir. |
| Commander | Oh Ken, |
| Intel Manager | Yes, sir |
| Commander | I need you to keep an eye on what higher's doing and how they are doing it for us. |
| Intel Manager | Will do. |
| Commander | And David, we have moving tracks beyond Marjorie, 2 of them, that would be suspected track 801 and suspected track 03. Go ahead and engage those please. |
| Blue | This is blue. SAR bird's inbound, will take 8 minutes to complere. Over |
| Commander | And Roger, Thank you very much. |
| Commander | Ah, David, on order I want you to launch Lams north into along the route to protect Brooks. |
| Effects | I already have one out there. |
| Commander | Yeah, your center with that, I didn't see one in the north. |
| Effects | Well we got… |
| | Ahhhh… |
| Effects | He's mine. |

| | |
|---|---|
| Commander | He's yours. |
| | Commint. |
| Commander | Double tap, I want him double tapped. Brooks, you take him too. |
| Intel Manager | And I've got a UAV that is just about to go there. |
| Commander | Excellent, excellent, good coordination. All three battle stations working together to kill that critical target on the battlefield and make our maneuver a success. |
| Effects | You sound like a damn commercial. |
| Commander | You liked that, huh? |
| Intel Manager | We cleared that area out. |
| Effects | Ahhhh… |
| Commander | Famous last words, there may be some tanks there we can't find. Anyhow. |
| Commander | What was that in the south there, Dave? |
| Effects | I'm having some iconage problem. |
| Commander | Alright. |
| Commander | Your micro went past him there. |
| Intel Manager | Hey you know what? |
| Commander | What? |
| Intel Manager | I've got the other one going towards him because… |
| Commander | Ok, you do whatever you have to do. |
| Intel Manager | If I went in there too early, he's got a chance of getting knocked down. |
| Commander | I'm with you. You do what you gotta do. I'm not telling you how to do it. I am just telling you what I want. |
| Intel Manager | Got it sir. |
| Commander | Hooah |
| Commander | Ah, it looks like all the Ugs are in. That's good. |
| Battlespace Manager | Unknown 9, center sector, MTI SAR. |
| Effects | Let me check him out on unit viewer real quick. Is he moving? |
| Intel Manager | That chaser round … |
| Commander | Yeah, it's ok. It's alright. |
| Commander | Due to the PAM hit. |
| Intel Manager | Roger |
| Commander | Whenever it hits. It's inbound. |
| Commander | Alright Brooks, you take that un…Ah, I don't know man, that unknown is bad. |
| Battlespace Manager | It's alright. |
| Commander | No, no, I mean I don't know, you know, if he's unknown, yeah that's what I'm talking about. |
| Battlespace Manager | Another radio, radio 12. |
| Effects | Where? |
| Battlespace Manager | I got him. |
| Effects | I can get him too. |
| Battlespace Manager | Let's put a cargo out there and see what we got. |
| Battlespace Manager | Another radio in scotch, you got that one. Unknown 13. |
| Effects | I got him. |
| Battlespace Manager | Got him? |
| Commander | OK, he seems to be moving north with some elements. |
| Effects | Unknown 9 bothers me. |
| Commander | Unknown 9 is… |
| Effects | Unknown mover. |

| | |
|---|---|
| Commander | Unknown 13 is beyond Leslie. |
| Effects | That's why it's bothersome. |
| Battlespace Manager | It's not moving. It was seen by SAR. SAR sweep got it. |
| Commander | Got which one? |
| Battlespace Manager | We got 100% confidence and its unknown. |
| Intel Manager | Center Sector there. |
| Commander | It's found by MTI though, it's moving. It's found by MTI. |
| Battlespace Manager | It was found by MTI SAR |
| Commander | Continue reading the sentence. It says using MTI. |
| Battlespace Manager | Probably a LAV. |
| Commander | Yeah, that's what I'm thinking. |
| Battlespace Manager | I'll put a tag on him temporarily. |
| Commander | Ok question, um, Dreaga chaser 7, Dreaga chaser 1. Are there 2 dreagas there or are there one Dreaga there? |
| Battlespace Manager | Where you talking? |
| Commander | Ken? |
| Intel Manager | Is that it on the FLOT? |
| Commander | Yeah |
| Intel Manat | I think there is one Dreaga there that..I… |
| Commander | I want a micro to check that, because in that position, he can kill Brooks coming out of the pass. I need to verify that that's dead. |
| Intel Manager | He was only fired upon one time. |
| Commander | Ok Dave, I might need you to double tap. |
| Effects | On? |
| Commander | I've got 2 Dreagas there, I've got 7 and 1. |
| Effects | Where? |
| Commander | Center sector, FLOT south of north. |
| Battlespace Manager | I'm looking at 14. |
| Effects | You're confusing me. |
| Commander | Heads UP |
| Effects | Yeah |
| Commander | Right here. I am worried that there's 2 tanks there, not one. OK? |
| Intel Manager | Alright. |
| Commander | Or maybe we killed a decoy. |
| Effects | Where? |
| Battlespace Manager | I'm thinking, go to heads up. |
| Effects | Show me. |
| Commander | Dave, reengage that for me buddy. |
| Battlespace Manager | That one right there, Chaser 14, that's a target. |
| Commander | Chaser 14. |
| Battlespace Manager | And that's whole,  no smoke. |
| Commander | Got it, Dave, you engage that with a PAM and engage |
| Effects | Which one? |
| Commander | Both of these I want you to engage. |
| Battlespace Manager | Right there, this is the image and there is no smoke coming and that's the chaser picture. |
| Effects | Ok, that's the one you shot at already, right? |
| Battlespace Manager | Yeah, I shot it with a cargo. |
| Effects | Ok, so shoot the chaser. |

| | |
|---|---|
| Battlespace Manager | So shoot that, yeah, Chaser 14. |
| Commander | Dave do you want someone else to engage that Draega 7? |
| Effects | No, I got it. |
| Commander | OK |
| Blue | Black6-Blue6 |
| Intel Manager | Ok, the radio unknown… |
| Commander | Blue-Black |
| Intel Manager | …good pictures |
| Blue | I've identified the ?? on the center sector unknown. I talked to your 2 already. |
| Blue | It's moving. But we need to wait to develop it. Over. |
| Commander | Are you talking about along the FLOT? Over. |
| Blue | But the problem with that is that you need to get eyes on it, but once you attack it, we won't be able to do that. Over |
| Commander | Roger, we're holding off on that right now. |
| Effects | How about the MTLB, what's happening over there? |
| Battlespace Manager | Sir, I made that unknown into an MTLB. |
| Effects | OK, so I got rounds in. |
| Battlespace Manager | Another radio. |
| Effects | I got him. |
| Commander | Ok, radio north, Dave, once you've got 7… |
| Effects | I've got it. |
| Commander | Radio link 15. |
| Intel Manager | Radio link 8 is dead. In the north, the first one in the north that one that was approaching us. |
| Commander | Are you keeping up with me there? |
| Effects | Yeah man, I'm there. |
| Commander | Got it. You're on it. Thank you. |
| Effects | LAM going in. |
| Commander | Good. |
| Effects | And I will… |
| Intel Manager | Ok there is another radio unknown, right underneath that Dreaga tank. In the, right |
| Commander | See I told you there was another one in there. |
| Commaner | Alright, the PAM. |
| Effects | I think I just got him. |
| Battlespace Manager | I think Dave just took him. |
| Commander | Yeah did it hit though? |
| | Ah |
| | Yeah it hit, but which vehicle? |
| Techie | Hey Brooks, can you turn your mike on. |
| Battlespace Manager | My mike is on. |
| Techie | Alright. |
| Battlespace Manager | Your welcome. |
| Intel Manager | Alright it was fired upon once. |
| Effects | LAM 11 hit. |
| Intel Manager | OK |
| Commander | Dave, when you get a minute, I want to get some more LAMs up north, please. |
| Battlespace Manager | Dave, he be a very busy man. |

| | |
|---|---|
| Commander | Dave is a busy man this time, and that's ok. |
| Intel Manager | UAV on its way. |
| Commander | Say, Ken, the micros are not helping me here. |
| Intel Manager | Yes they are, I've got |
| Commander | In the north, it is, but I want to go back at take a look at that FLOT picture of that Dreaga. |
| Intel Manager | It's on the way there. |
| Commander | Oh is that the one in the center going back? |
| Intel Manager | Going back. |
| Commander | OK good. Where's the fourth one? |
| Intel Manager | There's 3 in the north there. |
| Commander | Where's the one in the south? |
| Intel Manager | All 4 are in the north, there's one in the center heading back. |
| Commander | Ah I see, |
| Intel Manager | 2 of them are really close. |
| Commander | I got it, I see it now. |
| Intel Manager | I got 2 pictures of that dead |
| Commander | I'm with you. You're alright. |
| Battlespace Manager | Ok. All my snuffies are mounted. We are preparing to move. |
| Effects | Better run like hell. |
| Battlespace Manager | We shall. We're still a couple of minutes away from moving out. |
| Intel Manager | I can see my recon targets moving. |
| Commander | Alrighty now. |
| Effects | And be prepared to deal with the scoutage. |
| Battlespace Manager | Ok a PAM on chaser, on MTLB was a hit. |
| Effects | Yeah |
| Battlespace Manager | Vehicle was hit at radio unknown 6. Vehicle was hit at radio unknown 13. And vehicle was hit at radio unknown 14. So we are getting good fires in depth, but our radios are not transmitting anymore. |
| Commander | I'm, OK,… |
| Commander | Brooks, before we cross the FLOT, I want to make sure we cleaned up those Dreagas in the center. |
| Effects | I don't know how to do that for you. |
| Commander | No, no, no, micro UAVs headed there. |
| Intel Manager | Yeah, he's headed right there. |
| Battlespace Manager | I'd also like you to look on the south edge of the north wall. In that outer ridge of the north wall. |
| Intel Manager | At the edge of the north wall? |
| Battlespace Manager | Right now I'm talking to Jack. |
| intel Manager | Ok |
| Battlespace Manager | You've got to concentrate on what Jack told you to do. |
| Battlespace Manager | Jack, |
| Commander | Sir |
| Battlespace Manager | ...north wall up here |
| Blue | Black 6, Blue6, we've completed the SAR paint of T1. Over. |
| Battlespace Manager | ...based on what we had as far as the truck...we don't have anything up there. |
| Commander | I guess blue's telling me he completed the SAR paint for T1. Where's he gotta go next, T2? |
| Commander | And blue black, you completed T1 is that correct? |

| | |
|---|---|
| Blue | That's roger. |
| Blue | Got about 70% coverage of premium targets over. |
| Intel Manager | If he could cover T2 that would be the next step. |
| Commander | Roger, can you move to T2, please? |
| Blue | Standby |
| Battlespace Manager | We have an armor mover back there around Brown Debman. Armor |
| Commander | I wonder if |
| Effects | Talk to me, talk to me. |
| Battlespace Manager | I am just seeing a box for an armor indicator. |
| Commander | Is that MTLB dead? I don't see a lot of smoke on him. |
| Effects | All I know is that I hit him. |
| Battlespace Manager | Yeah, I'm reading based on what the PAM tells us. |
| Commander | Yeah but I'm looking at picture of him. |
| Effects | The picture there is pre-PAM. |
| Battlespace Manager | Yeah the picture was from the chaser. |
| Commander | Oh, I got it, I got it. |
| Battlespace Manager | Yeah the picture was from the chaser. The picture was from the chaser, and the |
| Commander | I'm with you. |